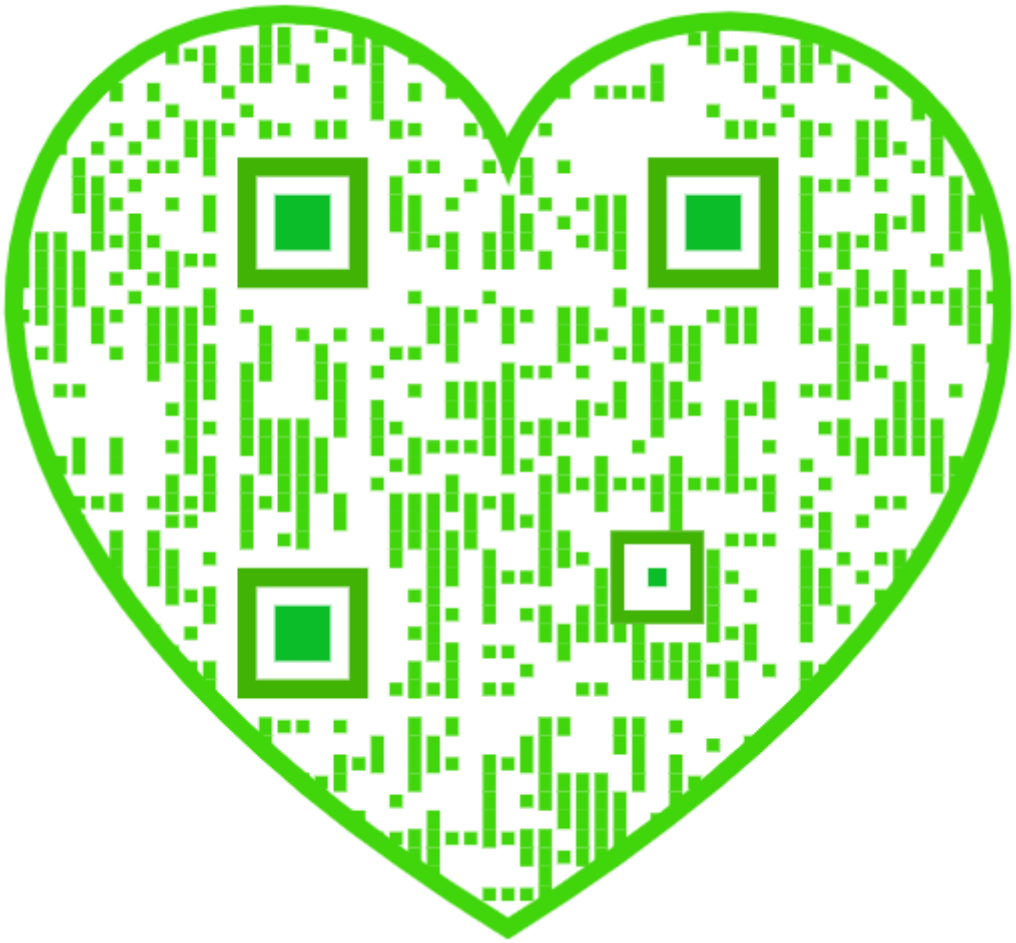

LESSONS

IN

ELEMENTARY BOTANY

FOR SECONDARY SCHOOLS

BY

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STATE UNIVERSITY OF IOWA

Boston
ALLYN AND BACON
1896

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PREFACE.

THERE are in general two ways in which the study of Botany may be approached. The first begins with the study of simpler plants, and proceeds systematically to the more complex. The second attempts, first, more familiar forms in their more striking phases, leaving more recondite problems for later inquiry and investigation. Of the two methods, the former has the advantage of being more logical; the latter is certainly more natural, and, in fact, corresponds with the manner in which all science has been developed.

In the present volume the second method has been followed. This for several reasons. In the first place, it seems more convenient. The very months when the simpler phases of plant-life are at their best are, by the present arrangement of our school year, practically excluded. But the phenomena presented by the higher plants are at least equally worthy of investigation, and are, as a rule, nearly always accessible.

Again, the study of the lower forms of plant-life cannot be carried far without the aid of more or less costly laboratories and appliances; and if the method adopted necessitates the study of such forms, the study of Botany will be restricted to such schools as can afford the requisite apparatus. However desirable such arrangement may be, there are hundreds of schools in

which such equipment is not likely to find place for many years to come.

Most of the work outlined in the lessons following can be managed with no more assistance than is offered by a Coddington lens. Even the few lessons at the end which enter the world of cryptogams are carried no farther than the pupil may go with his lens, aided here and there by such glimpses as a simple and inexpensive instrument may be made to yield to an entire class.

In the third place, it must not be forgotten that the schools exist for the sake of the children; and of any science those phases chiefly must be offered which shall be advantageous to the greatest number. Every child in the land should learn to know and love our common native plants, our trees; and if in so doing he should fail to reach the algæ, mosses, moulds, his lack in after life is not apt to be so seriously felt, by far, as if the situation were reversed. In any event, laboratory methods are as applicable in one case as in the other, and the true scientific training equally possible in both.

As the work in most of our high schools is now arranged, the study of Botany occupies the last half year, beginning about Feb. 1. The present lessons are adapted to such season. Trees, accordingly, seem to offer the most desirable objects with which to begin; and surely nothing could appear more advantageous. We have before us the spectacle of a great nation, absolutely ignorant of the principles of forestry. If the schools can so shape botanical instruction as to make it practical in the direction of a better appreci-

ation of the value of a tree, they may in so doing advance not the cause of science only, but of humanity.

The original plan of the book contemplated a joint authorship, in which Prof. B. Shimek, curator of the University Herbarium, should bring to the preparation of the lessons the benefit of his long experience as a teacher of Botany in the high schools. As it turned out, Mr. Shimek was prevented from doing all that was planned for him. LESSONS XI.–XX., inclusive, are, however, chiefly his work. His is also the note, *To the Teacher*, following, and Appendices A and D.

TO THE TEACHER.

One of the first requirements on the part of the teacher for the proper use of the following lessons is a good general knowledge of Botany, and of the flora of his own immediate locality. Without this knowledge no teacher can successfully teach Botany with this or any other text-book.

Pupils should be directed to study *plants* rather than the *book*, using the latter only as a guide in their work. For this reason it is necessary that certain materials be supplied beforehand, notably herbarium specimens of the plants to be used, together with other available local plants, dried specimens of fruits and seeds, wood-sections, and alcoholic specimens of buds, etc.

Since the work in Botany is now ordinarily commenced in the winter, most of the material must be collected and prepared during the preceding spring and summer months.[1]

Some remark may be necessary, relative to the amount of illustrative material called for. Experienced teachers will find here no difficulty; and those of less experience will find the preparation and accumulation of the necessary herbarium material not only a profitable and interesting exercise alike for teacher and pupil, but

[1] For list of materials, and methods of collecting and preparing the same, see Appendix A.

really almost a necessity, under any system of lessons, in view of the ever-increasing difficulty of securing illustrative material at all.

Much of the material will be serviceable year after year, and will not require replacing; a fact which will materially lessen the teacher's labor after the first year.

If any of the materials enumerated in the several lessons are not available, it is better that the terms or facts illustrated by such forms be for the time being omitted.

The pupils should not be restricted in their study to the forms listed, but should be required to procure other similar material for themselves, as far as possible, and work it up in the manner outlined in these lessons.

Nor should the study of plants be restricted to such fragments or specimens as can be brought into the schoolroom; but the pupils should be encouraged to go into the field with pencil and note-book, and make observations on the habits of plants, their mode of growth, usefulness, etc.

Drawings of most of the parts studied should be insisted upon; not drawings for artistic effect, but simple outline-drawings, without shading, which will *accurately* represent the organs or parts studied.

These drawings, however, should not be permitted to supplant full and accurate descriptions of the material studied, inasmuch as the development of ability to describe accurately is one object to be kept in view. But such drawings are an aid to memory, and they enable the teacher to judge more accurately of the pupil's ability to *see* correctly.

Each pupil should provide himself with a good lens (preferably a Coddington) and a sharp knife, together with a record-book, the determination of the exact character of which may be left to the teacher. A regular plant-record, a blank-book, or loose sheets of paper which may afterwards be bound together, are all useful.

The lessons need not be pursued exactly in the order in which they stand, nor, of course, are the species outlined the only forms that may be profitably employed as types. Any plant that offers may be brought to class, and studied as type of its group or order. The most profitable reviews are secured by the introduction of species other than those studied, and their reference to the appropriate order or family.

Where possible, it is better to have two consecutive hours for work. This may be accomplished by such arrangement of the course as will bring Botany on alternate days with some other study which likewise may occupy two successive hours, as drawing.

For LESSON VIII. special preparation must be made by sowing various seeds in suitable soil, and for LESSON IX. special advance preparation is needed.[1]

[1] See Appendix B.

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ELEMENTARY BOTANY.

LESSON I.

Buds and Their Arrangement.

Materials required: Twigs of various trees or shrubs, as many sorts as possible, such as Box Elder, Soft Maple, Elm, Willow, Birch, Oak, Apple, Cherry, Locust, Osage-orange, Horse-chestnut, Lilac.

I. Compare all the twigs. Note how very unlike they are. This unlikeness is due to various peculiarities, such as the character of the bark, the buds, the development or suppression of branches. Note that trees may be distinguished by their branches even, without leaves or flowers or fruit.

II. Take a single twig, the Box Elder, and note: —

a. The *leaf-scars*, uniting to form peculiar ring-like markings, occurring at quite regular intervals, more distinct toward the tip.

In the formation of each ring how many leaf-scars unite? By the aid of your lens determine their limits and describe.

Each leaf-scar, of course, marks the place of one of last year's leaves. The particular part of the stem which bears the leaf or leaves (two in this case, some-

times more or fewer) is called the *node*, and the part of the stem included between two successive nodes is called the *internode*.

b. The *buds*, each one just above a leaf-scar: opposite each other, therefore, in pairs up and down the stem.

c. Hold the stem so that any bud is directly towards you: call the side of the twig next you the front of the twig. Notice that the buds on the front are in line and alternate with buds to right and left on each side. The pairs of buds lie then alternately in different vertical planes. Buds or other organs so arranged are said to be *decussate*, decussately arranged.

d. Holding the twig as before, notice that the planes just referred to intersect each other at right angles and in the centre of the twig. The line of intersection of these planes, or of any planes so determined, is the *axis* of the twig or stem; lies in the direction of its principal development. In a wider sense the twig or stem itself is called the axis, because about it buds, leaves, or other lateral organs may be disposed.

e. Draw a diagram to illustrate a cross-section of the twig to show the position of the planes just referred to.

f. Notice that towards the tip of the twig the internodes become shorter, the last one shortest of all, so that the last two pairs of buds are brought very close together. Seen from the end of the twig these four buds occupy the entire circumference of the stem, as

would any other adjoining pairs if they could be looked at in the same way. Complete your diagram (*e*) by indicating upon it the position of the four buds just observed near the tip of the twig. What portion of the circle may be assigned to each bud?

Supposing the leaves still in position, how much of the whole space around the axis would fall naturally to each leaf, considering two nodes at a time? We shall see this illustrated presently when leafy stems can be procured.

g. Note that the twig (if uninjured) terminates in a bud. This is the *terminal* bud, distinguished thus from all the others, which together are called *axillary* buds.[1]

h. Draw a portion of the twig to show the leaf-scars and at least two succeeding pairs of lateral buds.

III. Compare now the twig of the Soft Maple: —

a. In a young, simple shoot the buds, though perhaps smaller, are disposed exactly as in the Box Elder twig. The leaf-scars are less conspicuous; the terminal bud perhaps larger.

b. Some of the twigs brought in may be of a preceding year, or may be farther developed, so that instead of buds there may be found, at some of the nodes at least, short branchlets. Note that these branchlets are decussately arranged; they may supplant all the buds on the lower portion of the twig or they may seem irregularly scattered, but in any case close examination will show

[1] Axillary, from axil. The axil is the angular space included on the upper side between the leaf and its stem.

that where there occurs a branchlet there is no bud, but the branchlet occupies exactly the place in which a bud was to be expected.

c. We may thus conclude that bud and branchlet are the same thing, differing chiefly in size and age; *a branchlet being a developed bud, and a bud an undeveloped branch.* Our future observations will serve to confirm this conclusion. (See LESSON IX.)

d. On such twigs as those considered in (*b*) and (*c*), not only will be observed branchlets, but on the branchlets will be found again buds of considerable size and in great numbers, crowded around the tips. These are *accessory* buds, and will claim our attention in a subsequent lesson. Crowded and heaped as these buds seem to be, we may yet discover their orderly arrangement, especially if we first consider the simpler clusters. On the younger portion of the budded stem we may find the lateral buds in place, but each flanked by single accessory buds. Farther down three buds may be found around the lateral bud. Apply this now to the branchlet, remembering that the terminal bud is to be expected on the branchlet as on the twig, and describe what you can make out.

LESSON II.

Buds and Their Arrangement — *Continued.*

Materials required: The same as in the preceding lesson.

I. Again compare all the twigs collected, this time especially in respect to the arrangement of their buds. Select for the sake of simplicity twigs that are free from branchlets and accessory buds, and note: —

a. That all the twigs may be divided into two groups according to bud-arrangement: those in which the buds are *opposite,* two at each node — this group includes the Maple and Box Elder; and those in which the buds are *alternate,* one at each node; the latter group includes probably all the rest of the twigs at hand.

II. ALTERNATE BUDS — THE ELM.

a. Take an Elm twig and hold it in its natural position; it drooped probably at the tip and is accordingly curved, the upper side convex, the lower concave. With your lens examine the leaf-scars; the bark is swollen just below so as to form a sort of shelf on which the leaf last year could rest and over which the axillary bud remains. The leaf-scar inclines toward the upper side of the twig and the bud toward the lower. This distortion results from the fact that in the Elm the leaves often expand in a plane nearly parallel to the axis, their edges towards the stem. As the leaves assume this position, the buds are crowded downwards.

b. Note now more closely the bud-arrangement.

How many buds at a node? Taking any bud as the first, where on the stem is the next one above (or below) to be found? the next? What is the position of the third with respect to the first?

The distance measured in degrees around the stem from a line, parallel to the axis, drawn through one bud to a line similarly drawn through the next bud above or below on the stem is called the *angular divergence* of the buds. This angular divergence of the buds, and of course leaves, in the case of the Elm is 180°. How much is it in the Box Elder?

c. Recurring to the Elm twig, note that the buds form vertical rows, but that of these there are but two. We have here accordingly the *two-ranked* arrangement of buds and leaves. Its best example is perhaps the Elm; although the grasses, as we shall see, exhibit the same arrangement. The same thing is true of the Linden. In the two-ranked arrangement, then, the angular divergence is one-half a circle, 180° more or less.

d. Suppose a thread fixed at one bud to pass around the stem through the next bud above to the third, such a thread will describe a spiral, passing *once* around the stem. In performing this experiment, when we come to the third bud, i.e., the one immediately above that with which we started, we complete a *spire* or *cycle.* The third (last) bud of any spire is counted the first of the spire next following above.

e. If Birch twigs are available, select slender, straight shoots of the last season, and note the arrangement of

the buds. Here the fourth bud is over the first, three occupy the entire angular space around the stem, the angular divergence is $\frac{1}{3}$ of 360°— 120°, and the arrangement is described as the $\frac{1}{3}$ cycle. If Alder twigs are obtainable, compare.

f. Compare now the Apple twig. What bud in order is directly above the first? Note that you must pass twice around the stem to reach it. What, then, is the angular divergence?

g. In all these cases note that the symmetry is not quite complete. We must use select branches. We must also attend carefully to trace the spiral, and the vertical rows are not as straight as we might expect. These irregularities are due to inequalities of growth, and these in turn are brought about by a variety of causes. For the axillary buds we have been examining, the position is determined by the place of the leaves, a bud for a leaf, and the leaves are disposed about the axis so as to be as little as possible in each other's way. We shall see this better when we have leafy twigs in hand, and we shall be able to trace clearly some of the causes which effect the lack of symmetry we have observed.

h. Compare the Locust twigs. The buds very small, or in some cases already developed as branches. The leaf-scar flanked on each side by a sharp thorn. Its presence here will be explained in a later lesson. The arrangement the same as the last. The number of rows, five; the number of turns in making the spiral, two; the angular divergence two-fifths of a circle. We may call

this the $\frac{2}{5}$ arrangement or cycle. If the bark of such a twig as that of Willow, Apple, or Locust could be peeled off in one piece for some distance and spread out flat, the outer side up, it would be observed that the buds occur in certain diagonal as well as vertical rows. The vertical rows have been already noted; the diagonal repre-

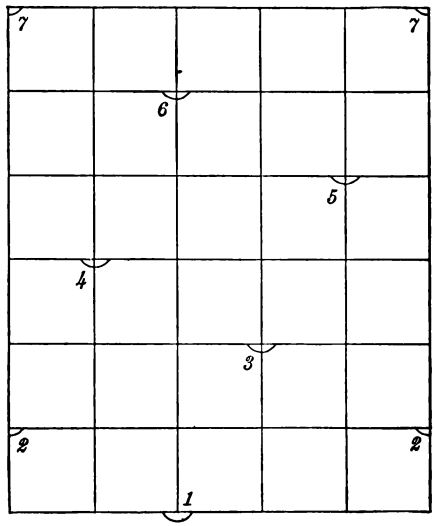

Fig. 1.

The $\frac{2}{5}$ arrangement of buds, leaves, etc., seen from the side, projected on a flat surface.

sent spirals (Fig. 1). Notice that in the fraction expressive of this arrangement the numerator, two, expresses the number of times we go round the stem in following one spiral from the first bud to the sixth; the denominator gives the number of vertical rows.

i. Study in the same way the twig of an Osage-orange. Note the leaf-scar, bud, and thorn at each node.

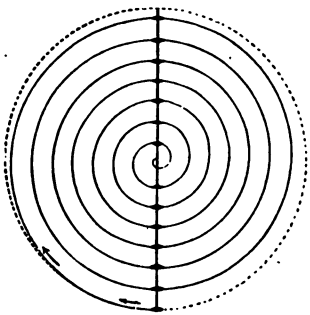

Fig. 2.

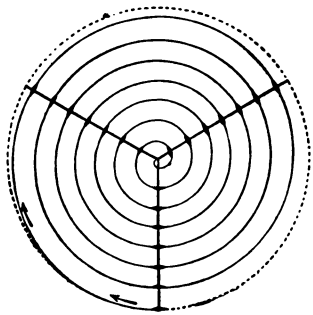

Fig. 3.

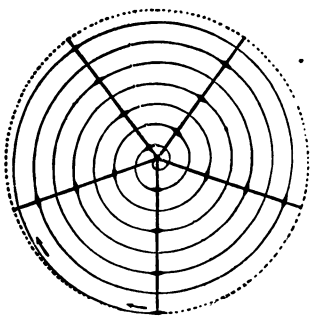

Fig. 4.

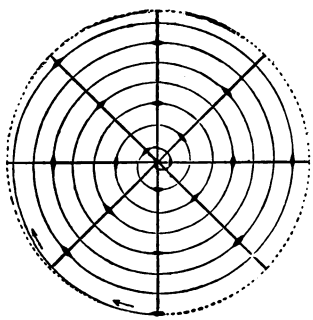

Fig. 5.

Diagrams to illustrate the spiral arrangement of buds, leaves, etc.

Fig. 2, the $\frac{1}{2}$ arrangement; Fig. 3, the $\frac{1}{3}$; Fig. 4, the $\frac{2}{5}$; Fig. 5, the $\frac{3}{8}$. After von Kerner. The positions of the successive leaves are indicated by shading.

The thorn represents probably a modified branch developed from an accessory bud. Draw a diagram like

Fig. 1 to show the arrangement of buds, thorns, leaves, in Osage-orange.

Further study of buds and their relation to branches may occupy our attention in subsequent lessons, when the buds may be had more fully developed.

LESSON III.

Stems; Their Structure.

Material required: The same twigs as before, omitting Locust and Osage as inconvenient to handle, but adding, if possible, Elder stems of the last season, Basswood, with twigs of Pine or Spruce.

Instruments: a *sharp* penknife and a good Coddington lens.

I. The Woody Twigs.

Cut each twig squarely and smoothly off, preferably in its thinner portion, and examine with the lens each in turn. The structure comes out a little better if the cut surface be slightly wet. Note: —

a. That each stem exhibits a threefold structure, — the *bark* or *cortex*, the *wood*, and the *pith*, sometimes called the *medulla*.

b. That these occupy always a definite relation to each other as regards position; what is this relation? and what is the form of each component part of the stem?

c. Draw a diagram to indicate the structure of such a woody stem as the Elder or Maple seen in cross-

section. The Elder is rather best to study because the parts are large.

d. Note the peculiar appearance of the white pith as if made up of small bubbles, minute sacs; these are the component *cells*, here large enough to be plainly seen with the Coddington. In the other portions of the stem, the cells are too small and crowded for present observation.

e. Supposing that we have an Elder shoot in hand; cut off a small piece an inch or two in length. With the point of the knife slit the bark down one side. With care, the *outer, corky* layer of the bark may be removed entire, exposing a softer green layer, which we may term the *middle* bark. Gently scraping away the green layer, we expose the *inner* or fibrous bark. This innermost layer, generally called also the *liber* or simply *bast*, is, as we see, tough and fibrous; compare the bark of the Willow, the Linden, or Basswood (Bastwood); any other twigs. Upon what depends the color of the annual twig in any case? Compare the Maple, the Willow.

f. If Pine, Spruce, or Balsam branches have been brought in, cut all the stems smoothly across and compare. Pith probably small, woody ring large, bark as before. Note, however, minute drops of resin oozing from the cut surface. From which part of the bark does the resin proceed? From the wood as well? Note the minute tubules, *resin ducts.* These are characteristic of "Evergreens" generally, though not discoverable in all. Compare, for instance, the twigs of Red Cedar.

g. Draw a diagram to show the place of the resin ducts.

LESSON IV.

Stems; Their Structure — *Continued.*

THE BARK.

THE primitive arrangement of the bark and its layers, as noted in LESSON III., persists usually but a short time; in some cases, however, much longer than in others. If the corky layer is to endure, it must be renewed from within. Such renewal is effected in much the same way in which the whole bark is renewed, and will be better understood after LESSON VI. In most trees the inner bark at length contains masses of hardened cells, thick-walled; as the stem grows older and larger the outer bark-layers split up and disappear while the inner bark remains, becomes cracked, and by exposure to the weather, blackened and otherwise modified.

Let the pupils go to the field and examine all accessible woody stems, and prepare a report, noting: —

a. The varying duration of the several layers which at first make up the bark, as observed in different cases.

This is best done by comparing the bark on the twigs and younger branches with that on the principal stems.

b. The different ways in which the bark breaks up and falls off, as exhibited in the case of different stems. Is it possible to recognize stems by their bark?

Compare such stems as the following: Elder, Currant, Grape, Apple, Cherry, Oak, Hickory, Elm, Hack-

berry, Maple, Cottonwood, Willow, Pine, Larch, Cedar, Birch, Sycamore, etc.

Such investigation and report may well occupy the time of more than one lesson.

LESSON V.

Stems; Their Structure — *Continued.*

THE WOOD.

Material required: Pieces of Cornstalk preserved in alcohol; pieces of dry Cornstalks from the fields; Elder shoots as before, especially such as show slender tips; herbaceous stems of accessible house-plants.

I. THE CORNSTALK.

a. The general structure; nodes; internodes; leaf-arrangement, perhaps still discernible; grooves in which axillary buds may lie.

b. In a cross-section of the stem, between the nodes, note the structure; the pith predominant; the bark entirely lacking; the wood represented by numerous fibres, *scattered* through the pith, more numerous toward the outside.

c. In the pith note the cells, large, very thin-walled but plainly identifiable, all very much alike; they together build up a vegetable tissue, when dry, as here, very light, very spongy. Such a tissue is called *parenchyma.* It is the tissue of piths and the soft parts of plants generally.

d. Examine now one of the fibres; it can be easily dissected out. Note its length, probably from node to node; its strength. If the end has been cut smoothly, note, under the lens, the large openings, about four; these represent tubes, *vessels* they are called; whence the fibre is called *vascular*. The fibres make up the *fibro-vascular* tissue of the plant, and each is called a *fibro-vascular bundle.*

e. Towards the margin of the section, the outside of the stem, not only are the bundles more numerous, but they are smaller and more and more packed together, yet maintaining pretty well their identity. This is best seen in an alcoholic specimen which has been cut off smoothly with a razor.

f. On the outside of the stem, closely associated with the outer bundles, find a thin layer of hard, smooth tissue, — the *epidermis.* Note that the entire arrangement of bundles and epidermis serves to give to the stalk its strength. Compare as to stiffness a pasteboard tube with an unrolled piece of the same material.

g. Draw a neat diagram to show the arrangement of all these structures as they appear on the cross-section of the cornstalk.

II. The Elder Twig.

Select twigs in which the youngest nodes are still preserved; cut the youngest internode (less than an eight of an inch in diameter) smoothly across, and wetting slightly the surface so exposed, examine with your lens, noting: —

a. The same threefold structure observed in the older twigs before, but — the woody cylinder observed before (LESSON III. I. *a*) is here represented by little masses, oval in section, arranged in a ring around the white pith. The number of these is not so great but that the larger at least may easily be counted.

b. Make a longitudinal section of the twig, and note that the oval sections just counted represent here as in the cornstalk, strands or fibres; these, then, are the *fibro-vascular* bundles of the Elder.

The component elements are so small that with a hand-lens we cannot discern the vessels as in the cornstalk, but we may presently under higher magnification see the whole structure very clearly. Meanwhile we may observe: —

c. The arrangement of the bundles, especially as compared with those of the cornstalk. There is in the pith of the Elder not so much as one; all are arranged with perfect regularity in a definite ring around the pith.

d. The bundles are separated at quite uniform intervals by portions of the pith which extend between them. These parts of the pith between the bundles are the *rays,* the *medullary rays,* parts of the *medulla.*

e. Draw a diagram to illustrate the arrangement of pith, bundles, rays, etc., in the young Elder shoot, and compare Fig. 8.

f. Compare cross-sections of the younger stems of available house-plants, — Begonia, Geranium, Petunia, Calla, Lily, etc. In some note how beautifully the com-

ponent cells come out, as in Geranium, in pith and bark. In Geranium and others note the thin epidermis covered with small white hairs.

In all we find but two types of structure, — the corn-stalk type in which the bundles are scattered, and the Elder type in which the bundles are plainly arranged in form of a distinct ring around the pith.

LESSON VI

Stems; Their Structure. — *Continued.*

THE CAMBIUM.

THE BUNDLES, OPEN AND CLOSED.

Materials required: Cornstalk, Pumpkin-vine, Maple twigs, etc., — short pieces of alcohol-hardened material; fresh twigs of various accessible trees; cuttings from house-plants, as heretofore.

I. THE PUMPKIN-STEM.

Take a short piece of a well-hardened stem, cut one end smoothly across; examine with lens in good light, and note: —

a. The absence of the central pith. The stem is naturally hollow.

b. The fibro-vascular bundles, some large, some small, few in number; count them. The figure of the section is a pentagon, and the arrangement of large bundles, at least, corresponds with this form. Draw an

outline of the section, and mark with an x the place of each bundle.

c. Examine one of the large bundles with the lens; note the mouths of tubes, vessels, near the middle of the bundle. These vessels mark the woody portion of the bundle. Toward the outside is a portion plainly different, showing no large openings; this is the cortical or

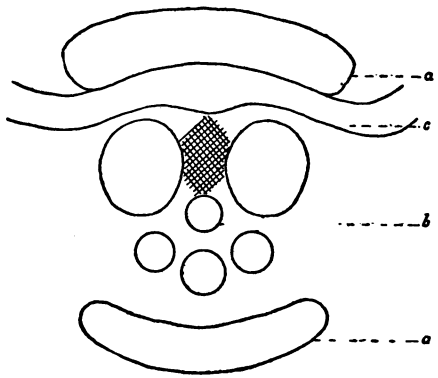

Fig. 6. Cross-section of a bundle of the Pumpkin-stem, diagram.
a. **Cortical portion (repeated below).** *b.* **The wood with large vessels.**
c. **The cambium layer. An *open* bundle.**

bark portion of the bundle. Between these two parts, — bark and wood,— in favorable specimens the *cambium* can be seen as a white band passing across the bundle. This sometimes shows better in thin slices cut with a razor, held toward the light, and examined with a lens. Under a microscope of moderate power the structure comes out perfectly, and at least one section should be examined at this juncture in this way. Such a bundle

as this where the cambium persists is called an *open* bundle. We shall see the effect of this presently.

II. The Cornstalk.

Cut a thin section of the cornstalk hardened in alcohol, hold to the light, and note: —

a. The beautiful lace-work formed by the *cells* of the pith.

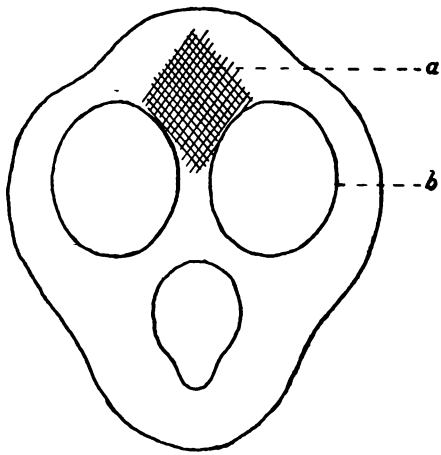

Fig. 7. Cross-section of the Cornstalk bundle, diagram.
a. Cortical portion, poorly developed. *b.* One of the large vessels of the wood. No cambium; a *closed* bundle.

b. The bundles, rather small, but showing: —

1. Large vessels forming the woody part, as in the Pumpkin-vine section; and
2. A much smaller part, destitute of large vessels, the cortical portion of the bundle. *There is no cambium.*

Put a section under the microscope, and the absence of cambium will be very apparent. Such a bundle as this of the cornstalk is called a *closed* bundle. (See Fig. 7.)

III. THE TREE TWIG.

Take a Willow twig about ¼ inch in diameter. Cut the end smoothly across with a sharp knife or razor, and note: —

a. The white pith, rather small, proportionately, in amount.

b. The wood, a cylinder quite well developed. In the section the medullary rays are seen as slender lines radiating in all directions from the pith.

c. The bark, separate from the wood by a fairly plain line of demarcation. This line (a faint ring, of course, on the end section) marks the place of the cambium of the twig or stem.

d. The bundles here are so numerous and crowded that we can scarcely distinguish them. We recall, however, that in younger twigs the medullary rays separate bundles (LESSON V. II. *d*), so that we may here consider as a bundle that part of the cylinder, in any case, limited on each side by rays. Compare a section of alcohol-hardened Maple shoot (Fig. 8).

e. In the twigs, then, the bundles with the cambium are like those of the Pumpkin-vine; i.e., *open*, but crowded so close together that the cambium from one bundle to the next becomes continuous, and so forms a sheath around the twig or stem, between the bark and wood, and having a common relation to both.

f. This cambium sheath, as seen in any thin section of a living twig, is made up of very delicate cells, like those of the pith, but much smaller, and even more thin-walled. Because of their minuteness and delicacy we cannot see them with the Coddington. It is the remarkable property of these cambium cells that they are competent to *grow*, so as to make, in one direction, — that is, outwardly, — *bark*, in the other, *wood*. This they do in the growing season. In fact, these cambium cells

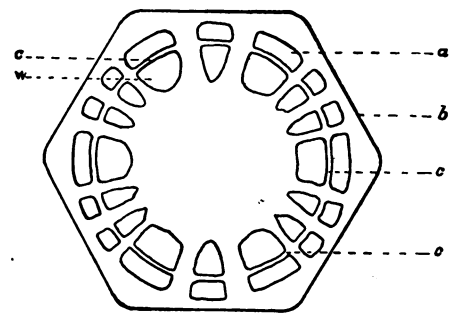

Fig. 8. Cross-section of young Maple shoot, diagram.

a. cortical part of bundle. *c.* cambium.
b. epidermis. *w.* woody part of bundle.

in the growing season do three things: they split up in planes parallel to the surface of the twig, and so increase their own number; some of them on the outside become changed into bark-cells, and so form a new layer on the inside of the bark; some next the wood become changed into wood-cells, and so add a layer of wood to that already in position. What the ultimate effect of this arrangement is will appear more clearly in the next lesson.

g. Cut all the twigs available, and find if possible the cambium line.

LESSON VII.

Stems; Their Structure — *Concluded.*

DIFFERENT KINDS OF STEMS.

Materials required: Seedlings of various sorts, — Beans, Corn, Wheat, etc.; sections of various stems, as Raspberry, Elder, Box Elder, Oak, Pine, Locust, etc.; section of a Palm stem if obtainable.

I. From our last two lessons we may now draw two or three well-defined conclusions: —

a. Note that the arrangement of the woody matter, the bundles, in stems is correlated with the structure of the bundle itself. Thus, when the bundles of a stem are scattered they turn out to be *closed* bundles; when arranged in a ring around the pith they are *open.* Experience will show us that this is the general rule; at least, the exceptions are so few that we need not heed them here.

b. Stems with scattered bundles have, when the bundles are mature, no *cambium;* stems whose bundles form a ring have *cambium.* It follows, if we remember the nature of the cambium cells, what they are competent to do (see LESSON VI. III. *f*), that only those stems whose bundles are arranged to form a ring are likely to increase in thickness.

c. Stems which increase in thickness by the activity of the cambium grow by an addition (successive additions) to the *outside* of the woody cylinder. Such

stems were long ago called *Exogens*, outside-growers; while stems with scattered bundles were called *Endogens*, inside-growers, because it was mistakenly thought that such stems could increase in thickness by the growth or addition of new bundles inside the stem.

II. Compare now growing seedlings of the Corn, Bean, Wheat. Find still another correlation. Note that the *Corn* in germinating sends up first but a single leaf; the *Bean*, on the other hand, starts with two opposite leaves, the thick halves of the seed. The plumule, or bud for the unfolding of subsequent leaves, lies between; but we may disregard that for the present. These primary seed-leaves are called *cotyledons*. Now, the stem of the Bean has its bundles arranged in a circle around the pith, and we may conclude that plants having the bundles scattered, as the Corn, have *one cotyledon.;* plants having the bundles in a ring have (at least) two *cotyledons*. This is a general rule, and our further experience will abundantly confirm it. Plants which, as the Corn, Wheat, etc., have but *one* cotyledon, are said to be *mono*cotyledonous; plants which have *two* seed-leaves, or cotyledons, are *di*cotyledonous.

III. These correlations may be placed in tabular form, thus: —

BUNDLES.	STEMS.	SEED-LEAVES.	PLANTS.
Scattered, Closed.	Endogenous.	One.	Monocotyledonous.
In a Ring, Open.	Exogenous.	Two.[1]	Dicotyledonous.

[1] In conifers the cotyledons are mostly several; more than two.

IV. We may now compare stems in still another important particular; viz., as to duration.

a. Make a list of all the plants you can recall, such as grow in yard and garden, and place the names in two series, according to stem-duration. Some plants, many plants, on the approach of winter die completely; others, as for instance Horse-radish, Rhubarb, die only to the ground; while still others persist, retain their stems at all seasons and from year to year. Stems which die down before the frost are called *herbaceous;* persistent stems are, by way of contrast, denominated *woody.* In our northern latitudes the woody-stemmed plants are all, except one or two, exogens; only in southern lands where there is almost perpetual summer do any of the endogens show persistent stems. Of these, Palm-trees offer the most notable example.

b. Compare now with each other several of the persistent stems: Rose, Raspberry, Blackberry, Elder, Box Elder, Cherry, Oak, Pine, etc. These, though woody, vary in duration. Which persist only one year? Which indefinitely?

c. Since exogens grow by external additions only, as described (LESSON VI. III. *f*), and since our climate offers alternate periods of growth and rest, it follows that each persistent exogen may in its structure keep a record of its years. Cut smoothly the ends of sticks of Pine, Oak, etc., and find the concentric lines of growth. Count the rings, and in this way estimate the age of the larger pieces. Try the same experiment with any stump or log to be found in the neighborhood and report.

d. This method is accurate except for the first year or two of development. Some stems (compare shoots of Box Elder) make two or three rings the first year, though uniformly only one per year thereafter.

e. In the mountains of California great trees have been cut down. On the stump of one as many as eighteen hundred rings are said to have been counted. How old was such a tree?

f. Notice that in any case only the outside of the stem lives. Hollow trees live and flourish as those that are solid. In some of the stems cut across note the two kinds of wood, distinguished by color, — *sap-wood*, white, and *heart-wood*, some shade of brown or yellow. Only the white sap-wood in general contains living tissue. The heart-wood, shut up inside the tree, ceases to live, but does not perish unless injured from without.

LESSON VIII.

Stems; Different Kinds; Special Forms.

Materials required: Dried specimens of Grape-vine attached by tendrils to its support; Virginia Creeper attached by disks; Morning-glory vine coiled around a string or pole; Cucumber or Pumpkin vine; Strawberry "runner," showing successive individual plants; in alcohol, root-stocks of Solomon's-seal, Trillium, Iris, May Apple, etc.; Potatoes, Tulip and Onion bulbs; a Cactus plant if convenient, etc.

So far our discussion of stems has concerned chiefly those which stand erect, and which agree pretty closely in structure with those we have used as types. Many stems, just as truly stems as any we have handled, yet differ very decidedly both in attitude, posture, or, as we generally say, *habit*, and in the *form* assumed consequent upon the discharge of some special function, or in obedience to peculiar circumstances.

I. As to HABIT, stems are: —

a. Erect. This is the common posture of our familiar plants. Let the student write a list of all the plants known to him which have erect stems.

b. Climbing. Many plants which apparently lack requisite strength in themselves yet manage to rise sometimes pretty high in the world by climbing. This is effected in various ways. Let the student make out a list of climbing plants of his acquaintance, and classify according to the means by which the ascent is accomplished. The Grape and the Morning-glory may be taken as two types. Later in the season the class may be made a committee to find out how the young Morning-glory plant, or seedling, manages to start and continue its spiral ascent around pole or string. Stems which ascend by coiling, as the Morning-glory, are sometimes called *twining* stems.[1]

c. Prostrate. Many stems run along the ground; and while the tip always or often may show a tendency to rise, nevertheless, the habit is prostrate, flat. The

[1] Read "Climbing Plants," by Chas. Darwin, especially chapter i.

Pumpkin-vine may be taken as an example. Let the student enumerate others.

d. Repent. Repent means creeping. Repent stems are prostrate, but attach themselves at intervals to the ground by more or less abundant rootlets. The Strawberry offers a familiar example. Others may be suggested. How about White Clover?

II. Stems assume SPECIAL FORMS for special reasons.

A. Many plants have *subterranean* stems: —

a. The simplest subterranean forms differ but little from repent stems above ground. Such are the stems of some grasses, for example, as Blue Grass, Quickset. In such case the stem is still stem-like in appearance, and simply pushes along under ground, sometimes just below the surface, sometimes deeper, sending up at intervals branches and leaves. Such a subterranean stem is called a *rhizoma* or *rhizome.* It may be either long or short. Compare the subterranean stems of Raspberry, Blue-flag, Bracken Fern, Solomon's Seal, Trillium. In what do these differ? Note that such plants also are *perennial.* *Cf.* LESSON VII. (IV.).

b. If the rhizome is greatly shortened, and very greatly modified in form, we have a *tuber.* A good illustration of such modification is the common potato.

c. Take a common potato and examine it carefully. What evidence do you find that this is a stem at all? What are the "eyes"? Note their arrangement. Compare potatoes that have sprouted in the cellar or in a damp, warm box. Look the specimen over with your

lens; note the surface cells. Over each bud observe a delicate, projecting scale. Observe at which end the potato was attached to the parent plant, and state the direction in which lie the scales. Considering the potato as a stem, which end is the top?

d. Split the potato through the middle lengthwise; find the ordinary parts of the stem; the pith, very large; the wood, a faint line around the margin of the section; the bark, rather thick, like the pith; the epidermis, seen plainly as the thin outer covering. Examine the section with the lens. Note the cells again; the woody line; the epidermis. Where the section passes through an eye, the woody line bends out to meet it. Touch with a weak solution of iodine the cut surface. What happens? What makes up the mass of the potato?

e. If you have a microscope, make with a razor a thin slice of the potato, and put the slice under the lens. Note the cells filled with minute granules. Try iodine again on the microscope slide. In what form, then, does starch in the potato occur?

f. Can any one tell what becomes of the potato when the sprouts grow, as when the potatoes are planted? Whence comes the material to make the sprouts? What, then, is the purpose of this strange modification of the stem that gives us the tuber?

g. Draw an outline of the potato-section to show diagrammatically the various structural peculiarities observed.

h. Compare, if convenient, a sweet potato. This is a root, not a stem. Are there here "eyes"? buds?

Perhaps irregularly scattered buds occur near the top. Buds that come out irregularly on different parts of a plant are called *adventitious* buds. We shall meet with such again.

i. Compare an onion. Cut it vertically in two; find the very short stem, bearing roots below, and abundant, swollen, thick scales around. The scales here, as may be seen by their tops, are leaf-bases. Such a structure, where the stem is very short and surrounded by such leaf-bases, is called a *bulb*. Compare, if convenient, a tulip-bulb.

j. In all the cases mentioned, and many others like them, the stem (in the bulb aided by the leaf-bases) discharges a special function, hence the extreme variation in form. What is the function?

B. Stems sometimes are peculiar in that they bear no leaves; a Cactus, for example. It is the business of leaves to be green, for what reason we shall see later on. We have already found that on young stems there is a green layer in the bark; in the Cactus and such stems, the place of the leaves is supplied by this green cortex.

That such a form as the Cactus is really a stem is proved, not by inner structure only, which might be shown to be dicotyledonous, but by the mode of growth as well; by the branching; by the flowers the Cactus bears, for, as will be shown, flowers also are branches of a special kind. Perhaps a blooming Cactus may be shown by some member of the class.

LESSON IX.

Buds Once More; Their Development.

Materials required: Young branches from trees, shoots a year or two old of the following species: Locust, Cherry, Lilac, Cottonwood, Hickory, Horse-chestnut, etc.; of the same species, as many as may be convenient, twigs that have been caused to grow in water in-doors (See Appendix B).

I. Note on different twigs the variations the buds exhibit as to size. Contrast the Locust and the Lilac, Hickory, Horse-chestnut. Note the difference as to size on the same twig.

II. The Lilac Twig.

a. Study the large buds near the tip. Review their arrangement. What was the order of the leaves?

b. A single bud. Note its shape. Cut it across with a sharp knife, and see the decussating pairs of bud-scales and undeveloped leaves. Examine with your Coddington, and draw in diagram. With the point of a needle dissect away, first on this side, then on that, the bud-scales. Note that only the outer are brown and hard, really to be called scales. The inner are soft and leaf-like. At last only a little short stem, or core, remains.

Make a vertical section through the middle and through opposing angles of a large bud. Examine with a lens. Note the pairs of young leaves arranged oppo-

sitely on the sides of the little stem. Draw another diagram to show what you can make out under the lens.

c. Compare now a bud that has been growing a few days. In what does growth consist? Note how even the outer scales stretch up and at length become green at base. What becomes of the core, or stem? In some cases developed as a young twig or branch, bearing the new leaves in order; in other cases, especially in the buds near the tip of last year's growth, expanded as a cluster of young flowers. Notice that flower-clusters and branches have the same origin, and stand related in the same way to buds and leaves. In the flower-clusters observe the branchlets. What arrangement do they show? In each flower how many parts are seen? All this is very suggestive. Note the dead flower-cluster of last year, probably yet hanging opposite a living (blooming) branch. The branch that in this case unfolds as a flower-cluster has no further function or history.

III. CHERRY–BUDS.

Make a vertical section through several buds on the Cherry twig, and compare. The lateral buds, perhaps all of them, contain each one or more tiny green buds in the centre, — flower-buds. Compare a twig on which the buds have begun to unfold. Note that the bud-scales are much less leaf-like than in the Lilac.

The terminal bud contains no flower-bud (as a rule). These terminal buds in the Cherry are leaf-buds, and the transition stages from scale to leaf can again be seen.

IV. COTTONWOOD–BUDS.

Compare as before lateral with terminal buds. Study the terminal bud; its form; outer scales, scarcely to be separated at all unless, in the process of growth, they have begun to separate of their own accord. Make a vertical section through the bud. Is it resinous throughout? Note the balsamic odor.

V. Compare in similar fashion the Soft Maple buds; Hickory, Horse-chestnut, if you have them. Note the velvety fuzziness of the scales in many cases, especially in the Hickory. What can be the use of such woolly or velvety structures? What of the resin in the Cottonwood-buds?

VI. Note that in all these cases the bud-scales proper loosen as the bud develops, and fall off, are *deciduous*. When a leaf falls, it leaves behind a scar; how is it with the bud-scale? Remembering that the unfolding of the terminal bud extends the twig, increases its length, follow back a little way, say on the Cottonwood twig, and find the position of the terminal bud a year ago. How many signs, indications, can you find that you have selected the right place? Compare in this way other twigs. How many years can you count back? Does the age in years determined by counting back the annual nodes on the twig correspond with the number of rings seen in a section taken across the twig just below the last (oldest) node counted?

VII. This peculiarity of the bud, by which it continues unvaryingly the branch or stem to which it belongs, admits of several practical applications. Thus, to recur

to the potato-tuber, — how are potatoes propagated in our gardens? By seed? When potatoes are cut in pieces for planting, why is care always taken to have on each piece an "eye"? What is Grafting? Budding? How does the gardener propagate house-plants? What are the little black bodies produced in the *axils* of the leaves of the tiger-lily? What are onion-sets?

LESSON X.

Roots.

Materials required: Sweet Potatoes, Beets, Turnips, Carrots, Parsnips, and such vegetables; with these, for comparison, a few common Potatoes; seedlings of various ages of the same species, Turnips, Beets, Corn, Wheat, Beans, Pumpkin, Melon, etc.; cuttings (rooted) of house-plants, such as Geraniums; a Cornstalk from the field, to show lateral roots at the base; a piece of the stem of Poison-ivy, preserved in alcohol, if convenient; dry stems of weeds affected by Dodder, etc.

I. Root and Stem.

It is a familiar fact that the plants about us consist, at least when growing, of three more or less distinct parts, — the stem, the roots, the leaves. Thus far we have been considering stems chiefly; let us now turn our attention for a little while to the roots of common plants, and try to discover their distinguishing features and characteristics.

a. Direction. We expect, of course, to find roots in the ground, and we know that their general direction is downwards; but let us compare various seeds, Corn, Beans, etc., that have been caused to germinate in various postures as directed (Appendix B). Notice that whatever may have been the position of the seed, the root always starts downwards into the darkness, the leaves and stem upwards towards the light. If the seed — grain of corn — has been wrong side up when planted, then the root turns as it grows, and finally takes its appropriate direction. For this reason the stem is sometimes called the *ascending* axis, the root the *descending* axis, of the plant. Sometimes the first root which leaves the seed, the *primary* root, continues to grow downwards, large and strong during the whole life of the plant, becomes a *tap-root.* Such a root has the Bean, the Beet, the Dandelion, many weeds, and in a more striking sense the Oak and the Walnut.

Compare now seedlings that are somewhat older, and note — for instance, in the Corn — the development of numerous other roots succeeding the first,— *secondary* roots. What has in this case become of the primary root? Such clustered slender roots as we have before us now are called fibrous roots. Such roots are characteristic of monocotyledonous plants; but compare the roots of the seedling Pumpkin or Melon. Draw a germinating grain of corn to show the opposite tendencies of root and stem.

b. As to Buds. All the stems studied in the lessons hitherto are characterized by abundant buds; how is it with roots?

Compare the Potato again with the Sweet-potato. The same tests which prove the Potato-tuber a stem (LESSON VIII. II. A, *h*) are sufficient, of course, to show that the Sweet-potato is not one. The adventitious buds of the Sweet-potato appear in spring all over it, and give rise to new plants. The roots of very many plants produce, especially if injured, adventitious buds. Compare what may be learned concerning the root-sprouting of the common Locust, the Cherry, the Silver Poplar, the Osage-orange. Nevertheless, it is the peculiar characteristic of the stem to bear buds for leaves and branches; and the root, if it have buds at all, bears adventitious buds only.

II. MORPHOLOGY OF ROOTS: i.e., a Comparative Study of Their *Forms*.

a. Take up seedling Beets, Carrots, Turnips, wash the roots free from sand, and compare as to shape with the plants offered as vegetables. Manifestly the primary root has in this case assumed special form. Where is the stem? Examine the crown of a full-grown Beet, for instance, and find the terminal bud. We may consider the stem in this case extremely short, its internodes not lengthened, but consolidated with the upper part of the root. When such a plant blooms, the stem generally stretches up, and the flowers are high in air. Perhaps some pupil has seen the garden Rhubarb in bloom. It may be examined later in the year.

b. Examine the base of a cornstalk that has attained maturity. Note the circle of roots sent out from the node nearest the ground. These are adventitious roots.

It is curious to notice that in this case the roots, as may be shown by several stalks cut at different ages, start in the air, *aerial* roots, and only at last are firmly imbedded in the earth. The Banyan-tree offers a famous example of aerial rooting (cf. any good cyclopædia), and the Screw Pine another. The most common example is afforded by the Poison-ivy (*Rhus toxicodendron* L.), a plant unsafe to handle, but perfectly manageable by sample in a museum jar.

Further examples of adventitious roots are shown in summer in every garden where Tomato-plants, for instance, left to themselves, take root where the stem happens to lie pressed to the ground. With suitable care almost any plant may be made thus to put forth roots from any part of the stem. What are cuttings? What happens when the end of a cutting is kept for a while in moist earth? Willow switches do very well for experiment. Does it matter which end goes down?

c. Study pieces of herbaceous stems, either dry or preserved in alcohol, affected by Dodder stems. Note how tightly the coils embrace the larger stems. Try to loosen them. The grip is made secure by rootlets that enter the tissues of the larger stem. The Dodder is a parasite; it has no connection (direct) with the ground, but steals its living from the larger plant, the so-called *host-plant*, into which the roots are sent.

III. Functions of Roots.

Considering all the cases we have examined, what may we conclude as to the functions of roots? Let the

pupil find three functions which roots perform, state them, and give reasons for his statement in each case:

1. For the first, the aerial roots of the Cornstalk may furnish a clew.
2. For the second, Turnips, Dahlia-roots, Sweet-potatoes.
3. For the third, the Dodder.

The function suggested by the Dodder rootlets is, we readily see, the most important of all. It is of advantage that the plant be held fast to the earth; it is also convenient to have such a place as the root in which, as in a cellar, to store that which may serve a future need; but first of all a growing plant must be *nourished*, and for terrestrial plants generally, as for the Dodder, nourishment enters the plant largely through the roots. It is a familiar fact that plants cut from their roots die. It is also a familiar fact that plants thrive only as they are supplied with water. Water enters the plant chiefly through its roots. Compare seedlings that have grown in moist soil with those grown in soil that has been allowed to dry. Furthermore, we must believe that plants derive from the soil much else besides water. Compare, for example, seedlings grown in damp soil with those grown in damp, clean sand, or in sawdust. Here the water supply is the same. What about the results? This difference also appears in our fields between plants growing in rich soil and those in sand or clay; which are finer? In general, we may say that the important function of roots is to supply the plant with water, and with such elements of its food-supply as are soluble in water.

LESSON XI.

The Leaf.

DURATION, ARRANGEMENT, PARTS, STRUCTURE.

Materials required: Twigs of the Maple or Box Elder, Pine or Spruce, Hickory, Lilac, Catalpa, Oak, etc.; pressed branches with leaves of the Larch, Gooseberry, Galium (Goose-grass or Cleavers), or Carpet-weed; fresh leaves and branches of cultivated Geranium; leaves of Amaryllis or Narcissus, and fresh or pressed branches of the cultivated "Smilax"; fresh or pressed leaves of other plants; a house-plant which has been in the dark for several days; seeds of the Bean, Pea, Corn, etc.

I. DURATION.

Compare the branches of the Maple and the Pine.

a. Note that the leaves of the Maple are wanting, scars only remaining to mark their position. Maple leaves are *deciduous.*

b. In the Pine the leaves remain on the branches all winter, and are *persistent.*

c. Compare the general aspect of Oaks and Maples with that of Pines and Spruces in winter. When do the Oaks and Maples lose their foliage? Do *all* the leaves die? How long do the leaves of the Pine and Spruce persist; i.e., on twigs of how many years' growth may leaves be found? Do the leaves finally fall, or do all that the tree produces persist?

II. Arrangement.

Note the position of the leaves or leaf-scars on the several branches.

a. In the Oak how many leaves were developed at each node? Such leaves are *alternate.*

b. How many leaves were developed at each node in the Maple or Box Elder? What position with reference to each other do they occupy? Such leaves are *opposite.*

c. How many leaves are there at each node of the Galium, or Goose-grass?

When each node bears more than two leaves they are *whorled.*

d. Notice that in the Larch and Gooseberry the leaves are crowded in a close cluster, hence are *fascicled.*

e. Draw two or three nodes of each kind, to show the position of the leaves.

III. Parts.

Take a fresh leaf of the Geranium, one still attached to a branch, and note: —

a. The long, slender stalk, or *petiole.*

b. The thin, expanded portion of the leaf, the *blade.*

c. The green leaf-like appendages attached, one on each side, to the base of the petiole, — the *stipules.*

d. With the Geranium leaf compare the leaves of the Maple, Amaryllis, or Narcissus, the cultivated Smi-

lax (*Myrsiphyllum*), etc. Is the petiole always present? The stipules? The blade?

In the Smilax note that the green leaf-like body is developed from the axil of a scale-like leaf, and is really a modified branch, or *clado phyllum.*

IV. STRUCTURE.

Study a large, fresh leaf of the Geranium.

a. With forceps strip off a portion of the outer covering of the blade. This is a thin, transparent membrane, — the *epidermis.*

b. Under the epidermis note the green pulpy *leaf-parenchyma* filled with *chlorophyl grains* which give to the leaf its green color. Compare the epidermis from the lower surface of an Amaryllis leaf, and under a Coddington notice the rows of minute openings, the *stomata.* Their function will be referred to presently.

c. Observe that the leaf-parenchyma is supported by a network of structures whose primary branches pass from the end of the petiole, and which are more prominent on the lower surface of the leaf. These are the *veins,* and their arrangement in the leaf constitutes the *venation* of the leaf. The largest veins, which are branches of the petiole, are called *ribs.*

d. Make a cross-section of the petiole, and with a lens note: —

1. The thin outer coat, or epidermis, appearing merely as a line, and better shown when stripped from the petiole with forceps.

2. The green, pulpy layer next to the epidermis, consisting of *parenchyma-cells* filled with chlorophyl grains.

3. In the centre a lighter-colored, pithy portion, in which may be seen a number of still lighter colored spots, fibro-vascular bundles in section.

4. Note that the largest one of these fibro-vascular bundles is found near the centre of the section, while the smaller ones form a circle near the outer part of the pithy portion of the petiole. Count the smaller bundles, and compare the number with that of the principal ribs in the blade.

e. Carefully cut away, with a sharp razor, a portion of the petiole and blade at their juncture, preferably from the upper surface (i.e., make a longitudinal section), in such a way that the central fibro-vascular bundles of each rib, and that of the petiole, shall be exposed. Note: —

1. That the central fibro-vascular bundle of the petiole branches, one branch passing into each of the ribs in the blade.

2. That one of the smaller fibro-vascular bundles of the petiole also enters each rib, accompanying the branch noted in 1.

f. If the leaf is freshly broken from the stem, the ends of the broken fibro-vascular bundles may be seen arranged in a crescent or semicircle on the surface of the base of the petiole, and likewise on the fractured surface of the stem; the fibro-vascular bundles pass from

the stem into the leaf, a fact which may be otherwise demonstrated by making a careful longitudinal section of a Geranium branch and the petiole of an attached leaf. The veins of a leaf are simply continuations of the woody or fibro-vascular systems of the stem.

g. Examine the leaf-scars on twigs of the Hickory, Catalpa, Buckeye, Lilac, etc., and notice in the scar points representing the ends of the broken fibro-vascular bundles.

V. FUNCTIONS.

a. Assimilation.

1. Place a living plant in the dark for some days. What changes take place in the color of the leaves?

   What changes take place in the color of a leaf which has been frozen? Of one which has been dried?

Compare a plant which has been kept in the dark with one which has been exposed to the light during the same time. Which has grown more? Does the first show any additional growth? Recall the changes which take place in the foliage of the Oak, Elm, etc., in the fall and winter. Does any growth take place after the leaves have changed and fallen?

These observations show that the chlorophyl bodies, which, as we have seen, make the leaves green, are developed and are active only in the presence of sunlight and a proper amount of heat and moisture. Under such conditions the work of assimilation is carried on by them; that is, the inorganic matters, chiefly water,

carbon-dioxide, and ammonia, taken into the plant (in solution by the roots, and in a gaseous state by the leaves), are, in the leaves acting in sunlight, made over into organic plant-substance.

Only green plants can use as food, assimilate, inorganic or mineral matters. This distinguishes them at once from animals.

2. If the foregoing statement is true, why do the Maple, Apple, Plum, etc., produce flowers (i.e. grow) long before their leaves appear? (See LESSON XXI.)

Can a potato grow in the dark? (See LESSON VIII. II. A.)

Will a seed sprout and grow underground, hence in the dark? Will the plantlet developed from the seed continue to grow if kept in the dark?

Test with Iodine various seeds, such as those of the Pea, Bean, Corn, etc.

In all the foregoing cases, and in all cases where growth takes place before the appearance of green leaves or other structures containing chlorophyl, growth is possible because starch or other food-substance had been stored up in some part of the plant for just such use.

Such food substances were prepared by the plant during the preceding season by the aid of green leaves, and they are already organic substances which may readily be used by the plant without the aid of chlorophyl.

b. Transpiration.

1. Expose a fresh leaf or detached branch to the air of a warm room for a few hours. What is the result?
2. Compare a similar branch which has been placed in a tumbler of water. What does the difference between these branches indicate?
3. What is the difference between plants which have been abundantly watered, and those which are grown in dry soil?
4. Place a fresh leafy branch of any house-plant under a bell-glass, or in a glass jar which can be closed. In the course of an hour or more what has collected on the wall of the jar or bell-glass? Whence does it come?

These experiments indicate that a plant takes up, and again gives off, large quantities of water. Most of this water acts merely as a solvent and carrier of the inorganic substances used by the plant for food. When this food has been assimilated the surplus water again passes from the plant in the form of vapor.

This exhalation of the surplus water in the form of vapor takes place through the stomata already mentioned, and is called *transpiration.*

c. The principal functions, then, of ordinary green foliage-leaves are those of assimilation and transpiration.

For special forms of leaves which serve as storehouses of food, for protection, as tendrils, floral-organs, etc., see Lesson XV. VI., and the lessons on the flower.

LESSON XII.

The Leaf.— *Continued.*

VENATION.

Materials required: Herbarium or fresh specimens of the leaves of the following plants: Flowering Fern, Elm, Hazel, Apple; cultivated Geranium, Maple; Amaryllis or Narcissus, Day Lily; Canna.

I. Examine the lower side of a fragment of the frond of the Flowering Fern. Note: —

a. Each one of the smallest divisions of the frond has a distinct vein running through the middle, the *mid-rib.*

b. From each mid-rib pass out numerous smaller veins or *veinlets.* Do these form a network? Do any or all of them fork? Do the branches again divide? Into how many branches does a vein divide at any given point of branching?

Such forking venation is called *furcate,* and is characteristic of ferns.

c. Draw a bit of the frond showing venation in detail

II. Examine the lower side of an Elm leaf. Note: —

a. The prominent central vein, a continuation of the petiole, the mid-rib.

b. The smaller veins, or *secondary ribs,* running obliquely from the mid-rib, arranged like the barbs of a

feather; hence the leaf is said to be *pinnately-veined,* or *feather-veined.*

How many secondary ribs are there? Where do they terminate?

c. The small *veinlets* forming a network between the secondary ribs; hence the Elm leaf is described as *netted-veined,* and being pinnate, it is said to be *pinnately netted-veined.*

d. Draw the outline of the leaf, and show the venation in detail.

e. Compare the leaves of the Hazel and Apple with that of the Elm. Is the general arrangement of the larger veins the same? Do the veinlets form a network? Is the general plan of venation the same? Is there any difference in the details of venation?

III. Examine the lower surface of a Geranium leaf. Note: —

a. The seven nearly equally prominent *ribs,* diverging from the end of the petiole like fingers from the palm of the hand; hence the leaf is *digitately* or *palmately veined.* How and where do the ribs terminate?

b. The smaller veins and veinlets, uniting to form a more or less distinct network; hence again *netted-veined,* but now *palmately netted-veined.*

c. Draw an outline of the leaf, and a portion of the venation in detail.

d. Compare the leaf of the Maple. Is the general plan of venation the same? How many ribs does the Maple leaf have? Compare the details of venation.

IV. Examine the leaf of Amaryllis (or Narcissus). Note: —

a. The very prominent central mid-rib.

b. The numerous smaller veins, sometimes called *nerves,* which extend from the base of the leaf to the apex. Do any of these veins unite? Are there smaller veinlets crossing between the veins?

Since the veins are approximately parallel, and do not form a network, the leaf is said to be *parallel-veined;* and as they diverge from the base it is again *digitately* or *palmately veined:* hence the leaf is *palmately parallel-veined.*

c. Draw an outline of the leaf and a portion of the venation in detail.

d. Compare the leaf of the Day Lily. Is the general plan of venation the same? Note the difference in the number and size of the veins.

V. Examine a Canna leaf. Note: —

a. The prominent mid-rib.

b. The veins running out obliquely from the mid-rib. Where do they terminate? Do they unite, either directly or by cross-veinlets, to form a network?

Note again the feather-like arrangement of the veins; hence the leaf is again pinnately-veined, but now *pinnately parallel-veined.*

c. Draw the leaf and a portion of the venation in detail.

VI. Have various leaves of house-plants brought in, and compare the venation with the foregoing types.

LESSON XIII.

The Leaf. — *Continued.*

FORM, BASE, APEX.

Materials required: Fresh or herbarium specimens of the leaves of the following species: Carnation, Fuchsia, Common Locust, Black Willow, Purslane, cultivated Nasturtium, Morning-glory, Red Clover, Ground Ivy, Calla, Shepherd's-purse (the whole plant), Pine, Red Currant, Verbena, White Elm, Common Thistle, Bellwort, Honeysuckle, and such other forms as may be conveniently obtained.

I. FORM.

a. Make a general comparison of the leaves. Notice the great variation in the dimensions of the several forms, the series ranging from those which are long and very narrow, to those which are almost circular in outline.

Three general groups of forms may be recognized: —

1. Those which are widest near the base, and taper toward the apex.

   The terms *lanceolate*, *ovate*, *cordate*, *sagittate*, and *reniform* describe the most common forms.[1]

2. Those which are widest near the apex, and taper more gradually toward the base. The terms *spatulate*, *cuneate*, *oblanceolate*, *obovate*, and

[1] For explanation of these terms, and all others used in this lesson, see Glossary, Appendix D.

obcordate describe the most common forms, the last three being respectively like the lanceolate, ovate, and cordate forms reversed.

Select specimens from the series of leaves to which these terms may properly be applied. Make an outline sketch of each.

3. Those which are widest at the middle, and taper equally toward base and apex. The terms *linear, needle-shaped, oblong, elliptical,* and *oval* describe the most common forms.

Select forms represented by these terms from the material in hand, and draw each.

Notice that the general outline of some of the leaves cannot be satisfactorily described by any of the terms in the preceding groups, the forms being intermediate between the members of one group, or even of different groups.

In such cases combinations similar to the following must be employed: *ovate-lanceolate, linear-lanceolate, oblong-ovate,* etc.

b. Compare the several leaves, and notice the relation which general outline and venation bear to each other.

II. BASE.

a. Compare the bases of the several leaves, and notice that in many cases the form of the base does not appreciably modify the general outline of the leaf, and also that leaves of different forms may have bases of essentially the same kind. The bases vary from those which are narrow and tapering in form to those in which the margin at the base forms a re-entrant angle, the outer angle, or *sinus,* being acute or obtuse.

The following are the most common terms applicable in describing the bases of leaves: *cuneate, acute, obtuse, truncate, cordate, reniform, sagittate, auriculate, peltate, perfoliate, connate-perfoliate, decurrent.*

It will be observed that some of these terms are the same as those applied to the general outline; but they are here used in a restricted sense, applying to the base only.

b. Select forms from the series of leaves to which the above terms may be applied, and make an outline sketch of each base.

III. APEX.

a. Compare the apices of the several leaves, and note that the general outline of the leaf is affected even less by the form of the apex than by that of the base.

The most common forms of the apex are the following: *obcordate, emarginate, obtuse, truncate, cuspidate, acute, acuminate, mucronate.*

b. Apply these terms as far as possible to the specimens under observation, and make sketches to illustrate the various forms of apices.

Prepare an outline of all the terms in this entire lesson which can be illustrated by the material in hand, and illustrate each term by a small outline drawing made from the specimen. Such a classified illustrated outline of terms will be very convenient for reference in describing plants.

LESSON XIV.

The Leaf. — *Continued.*

MARGIN, DIVISION OF BLADE; COMPOUND LEAVES.

Materials required: The leaves mentioned in the preceding lesson; fresh and herbarium specimens of the leaves of the following additional species: Cherry, Common Violet, cultivated Geranium, Burdock, Hawthorn, White Oak, Maple, Peppergrass (entire young plants), Golden Currant; also Rose, Pea, Honey Locust, Red Clover, Sweet Clover, Rue-anemone, Barberry, Orange, and any other available species.

Examine the entire series of leaves, and notice that they may be separated into three series or groups: 1. Those in which the blade of the leaf is not at all, or but slightly, cut at the margin, the incisions, or *sinuses*, if any, extending much less than half-way to the mid-rib, or end of the petiole. 2. Those in which the blade is more deeply cut, the incisions extending quite half-way, or more, toward the mid-rib, or base of the leaf. 3. Those in which the blade is divided into several separate divisions.

I. MARGIN.

a. Compare the leaves of Carnation, Cherry, White Elm, Common Violet, Geranium, Burdock, Hawthorn, etc.

Notice the varied character of the margin, which, however, is in no case deeply cut, the extremes in this

series being represented by the *entire* margin of the Carnation leaf and the rather deeply *incised* margin of the Hawthorn leaf. The various forms of the margin are described by the following terms: *entire, serrate, dentate, crenate, undulate, sinuate, repand, incised.*[1]

In some cases the marginal teeth, of whatever form, are very small; and for these the following terms are used: *serrulate, denticulate, crenulate,* according as the margin is finely serrate, dentate, or crenate. Sometimes, as in the Elm leaf, the margin is coarsely serrate, and the serrations, or teeth, are again serrate, the margin then being *doubly-serrate.* Similarly, the margin may be *doubly-crenate* or *doubly-dentate.*

b. Apply the terms as far as possible to the leaves before you, and make an outline sketch of a portion of the margin of each leaf studied.

II. Division of the Blade.

a. Compare the leaves of White Oak, Maple, Peppergrass, Golden Currant, Thistle, etc.

Notice that the depth of the sinus varies, but in all these leaves it extends more than half-way to the midrib, or the base of the leaf. To express the difference in the depth and character of the cutting of the blade, the following terms are employed: *lobed, cleft, parted, divided.*

b. Notice also that the mode or plan of division is of two kinds, *pinnate* and *palmate,* conforming to the kind of venation. (See Lesson XII.) Hence the leaves

[1] See Glossary.

are *pinnately lobed, cleft, parted,* or *divided;* or *palmately lobed, cleft, parted,* or *divided.*

Pinnate leaves may also be *pinnatifid,* or *runcinate.*

c. Apply the preceding terms to the specimens before you, and from the latter make outline sketches to illustrate the several forms.

III. Compound Leaves.

a. Compare the leaves of the Rose, Pea, Honey Locust, Red Clover, Sweet Clover, Rue-anemone, etc., with those studied in the preceding groups. Note that the latter all have the blade in one more or less continuous piece, being therefore *simple,* while the former all have the blade divided into separate divisions, or *leaflets.* Most of the leaflets have distinct stalks, or secondary petioles, called *petiolules,* which are more or less distinctly joined to the mid-rib, or end of the petiole. The last character, together with the complete division of the blade into leaflets, characterizes *compound leaves,* and constitutes the difference between many *divided* and nearly all *compound* leaves, though the characters are by no means always clear.

b. Compare the leaf of the Barberry. If the leaf has been carefully removed from the branch, it will be noticed that the leaf-stalk is distinctly jointed near the base. How much of the leaf-stalk is petiole? How much petiolule? How many divisions of the blade, or leaflets, in this leaf?

The Barberry leaf is a compound leaf with one leaflet. Compare the leaf of the Orange if available.

c. Examine the several leaves again. Why is not

each one of the leaflets considered a leaf? Are there buds in the axils of the leaflets? Of the whole leaf? (See Lesson I.)

d. In this series of leaves notice the variation in the *number* of leaflets, and also in the manner of division, the leaflets in some being arranged in the *pinnate* order, such leaves being *pinnately-compound,* and in others *palmately,* such leaves being *palmately-compound.*

e. In the pinnate leaves notice the difference in the arrangement of the leaflets, one or two leaflets, or a tendril, terminating the leaf. The leaves are therefore *odd-pinnate, even-pinnate,* or *cirrhosely-pinnate.*

f. Notice, also, that both the palmate and pinnate leaves may be more than once compound; i.e., they may be *twice* or *thrice pinnately* or *palmately compound,* or they may be *pinnately* or *palmately decompound.*

Prepare an illustrated outline of the terms employed in this lesson, making the outline sketches from the specimens studied.

LESSON XV.

The Leaf.— *Concluded.*

COLOR, SURFACE, TEXTURE; VERNATION; SPECIAL FORMS.

Materials required: See list under each sub-head.

I. COLOR.

Examine the fresh leaves of cultivated Geranium (both green and variegated forms), Carnation, Oleander,

Amaryllis, Fuchsia, Begonia, etc.; also herbarium specimens of Painted Cup.

a. Notice that some of the leaves are much deeper green on one side than on the other, such leaves having a distinct *upper* and *lower* (or dorsal) face, while those which are of nearly the same color on both sides are usually erect, or stand with both faces about equally exposed to the light. (See LESSON XI. IV.)

b. Compare the colors of the several leaves. Notice that the chlorophyl-green of some of them is more or less obscured or modified by other colors, some of which belong to the body of the leaf, while others are produced by surface appendages, such as hairs, scales, etc.

Describe the colors of the various leaves.

c. In the Painted Cup notice that the bright-colored red leaves are clustered at the end of the stem, near the flowers. These perform the functions of showy floral parts (see LESSON XVII.), and are called *petaloid leaves.*

II. SURFACE.

Examine the surfaces of the leaves of the plants mentioned in the preceding group; also fresh leaves of Petunia, and herbarium specimens of leaves of the Sunflower, Hazel, Mullein, Blackberry, Burdock, etc. Notice that some are entirely smooth, i.e., free from surface appendages, while others are variously clothed with minute waxy particles, glands, hairs, scales, or spines, these differences giving rise to the use of the following terms: *glabrous, glaucous, scabrous, glandular, pubescent, puberulent, woolly, tomentose, villose, floccose, spinose.*

Apply these terms as far as possible to the specimens before you.

III. TEXTURE.

Leaves differ also as regards their thickness and texture. Compare the fresh leaves already mentioned, and also fresh leaves of English Ivy, Ice-plant, etc., and notice that the terms *membranous, herbaceous, coriaceous, succulent, etc.*, express the differences between them in this respect.

IV. VERNATION.

The manner in which the blade of the leaf is folded in the bud, or the *vernation* of the leaf, is also of interest.

a. Take fresh leaf-buds of Geranium and other house-plants, and alcoholic specimens of leaf-buds of Ground-ivy, Oak, Apple, Fern, Currant, Common Violet, Yellow-dock, etc.,[1] all of which should be collected when the leaves are beginning to unfold.

Pick the buds to pieces, observe the various ways in which the leaves are folded in the bud, and apply the following terms, expressing kinds of vernation: *straight, inflexed, conduplicate, convolute, circinate, plicate, involute, revolute.*

b. Make diagrams or sketches from the specimens to illustrate the kinds of vernation.

V. THE PETIOLE AND STIPULES.

The leaf has thus far been considered with special reference to the blade. The remaining parts of the leaf, the petiole and stipules, also require attention.

[1] The alcoholic specimens should be soaked in water for a few hours before being used.

a. The Petiole. Compare the leaves of Geranium, Willow, Carnation, Plantain, etc., using fresh or herbarium specimens. Notice the variation in the following characters: —

1. Length, — the petiole being long or short, or even absent, in which case the leaf is *sessile.*
2. Form of cross-section, — being *compressed, terete, grooved,* etc.
3. Surface and color, — the variation in these characters being the same as in the blade.

b. The Stipules: —

1. Search for the stipules in the leaves of the Willow, Clover, Greenbrier (*Smilax*), Common Locust (with branch), Smartweed, Rose, Maple, etc. In herbarium specimens be sure that the entire leaf is collected; notice that the stipules vary greatly in size and form, the form, margin, and apex assuming the forms exhibited by the blade. Are the stipules always present?
2. Notice that the stipules are often green and leaf-like, or membranous; but they may be of special forms, being sometimes changed to *tendrils, spines,* or *sheaths.*

c. Make a full description of the stipules of the leaves before you.

VI. Special Forms of Leaves.

Materials required: Fresh branch of Lilac which has been in water for days, so that the buds are somewhat developed; herbarium specimens of leaves of the Pea;

branches (including those of the season in which they were collected) of Barberry and Gooseberry; fresh specimens of Onion, Potato, and alcoholic specimens of the rootstock of Solomon's-seal, or Mandrake. The leaves heretofore considered nearly all serve the purpose of ordinary foliage-leaves; i.e., they are chlorophyl-bearing, assimilating organs of the plant. Many leaves, however, serve other purposes than this, the more common and striking of these special forms being the following: —

a. Bud-scales. That these are leaves is clearly shown by the Lilac, in which there is a gradual transition from the outer brown bud-scales to green leaves. (See LESSON IX. II.)

b. Tendrils. The Pea exhibits a modification of a part of the leaf into tendrils. Do these tendrils branch? Notice the arrangement of the branches. To what do they correspond?

c. Spines. Examine the branches of Barberry. Note the spines, some single, others three-parted. Observe the arrangement of these spines on the stem. Are there buds or branches (developed buds) in their axils? *If so, the spines are leaves.*

On the young shoots, notice that some of the spines have their three lobes connected by a web, the spines on these shoots, in fact, showing a gradual transition from the true leaf to the spinous state. To what part of the leaf do the spines correspond? Compare the spines of the Gooseberry.

d. Bulb-scales.

1. Examine the bulb of an Onion, preferably one that has sprouted. Notice that the outer coats are membranous, each one bearing a fragment of a dried leaf above. Remove these, and notice that the inner coats are fleshy, each also bearing a part of a leaf. Remove some of the fleshy coats, and notice that on some of the innermost coats the leaves are perfect.

   The scales, or coats, are fleshy bases of leaves.

2. Make a longitudinal section of the bulb through the centre, and apply the test given in *c*. Do you find buds in the axils of the outer scales? Of the inner ones?

3. Compare the scattered scales on other forms of underground stems, such as the rootstocks of Solomon's-seal, or Mandrake, and apply the same test. Are they leaves?

   What is the minute scale on the lower side of the "eye" of the Potato-tuber?

e. Fly-traps and Pitchers. Leaves may be peculiarly modified for the purpose of entrapping insects, as in the case of Fly-traps and Pitcher-plants; and these should be noticed if specimens for illustration are available.

f. Leaves modified into *bracts*, and into *floral organs*, will be discussed in subsequent lessons.

Write a full discussion of the special forms of leaves, stating in each case the reasons for the belief that they are leaves.

LESSON XVI.

Inflorescence.

Materials required: Herbarium specimens of flower-clusters of the following plants: Larkspur, Mandrake, Shepherd's-purse (both young and old clusters), White Ash, Lily-of-the-Valley, Wild Sarsaparilla, Carrot, Plantain, Wheat, Poplar, Blue Grass, Grape, Phlox, Elder, etc. (The fruit-clusters of many of the species, dried without pressure, will be quite as useful). Also fresh flower-clusters of Geranium and Calla.

I. Make a general comparison of the several flower-clusters. Note the differences in the compactness of the clusters, their form, size, and number, and arrangement of the flowers in each.

These characters determine the mode of flowering of the plant, its *Anthotaxy*, or *Inflorescence.*

II. Parts of the Flower-cluster.

Examine the flower-cluster of the Larkspur. Note that: —

a. The flowers are arranged along a central stem, or floral axis. Observe: —

1. The part of the axis included *in* the flower-cluster, — the *rhachis.*
2. If the naked stem be continued below the lowest flower to form the stalk of the flower-cluster, it forms a *common peduncle.*

Sometimes the peduncle rises directly from the ground, — a *scape*. (See LESSON XXIX. II. *a*.)

3. The individual flower attached to the rhachis by a stalk, — the *pedicel*.

b. Each pedicel springs in the axil of a small, narrow leaflet, the *bract*. When several bracts, or leaves, are set to form a whorl beneath a flower or flower-cluster, they constitute an *involucre*.

In the plants before us, notice that the bracts vary in length, color, surface, general outline, margin, and apex, much as leaves do.

What are bracts, as determined by their position, and the form and structure of many of them ?

c. Compare the several flower-clusters again. Is the rhachis always distinct ? The common peduncle ? Are the pedicels always present ? Flowers without pedicels are said to be *sessile*.

May the flowers be without bracts and bractlets ?

III INDETERMINATE INFLORESCENCE.

Notice the position of the flowers in the Larkspur and Shepherd's-purse.

a. Are any of them terminal on the stem ? Notice that the lowest flowers in each cluster are the first to open, the remaining ones opening successively upward. Such order of inflorescence is said to be *indeterminate*, or *centripetal*.

What is the origin of these terms ?

b. Select all the clusters of the indeterminate kind from the series in hand, and compare them. Notice that they may readily be divided into two classes:

1. Those in which the flowers have pedicels; i.e., *pedicellate.*
2. Those in which the flowers are without pedicels; i.e., *sessile.*

c. Among the pedicellate kinds the following forms may be recognized: —

1. Flowers, several or many, on elongated rhachis; pedicels nearly equal, the flower-cluster being a *raceme.*
2. Flowers as in 1, but the lower pedicels elongated so that the lower flowers are brought up to nearly the level of the uppermost ones. The cluster is nearly flat-topped, and is called a *corymb.*
3. Rhachis wanting, the pedicels all proceeding from the end of the common peduncle, — an *umbel.*

d. Of the clusters with sessile flowers the following are the most common forms: —

1. Flowers closely arranged on an elongated axis, the cluster being a *spike.*
2. Loose, usually drooping, forms of 1; flowers mostly small, and with scale-like bracts, — the cluster being a *catkin.*
3. Erect, rigid spikes enclosed in a leaflike or petaloid bract called a *spathe.* The flower-cluster is a *spadix.*

4. Like 1, but the floral axis very short, so that the length of the cluster is scarcely greater than its diameter. The cluster is a *head.* The enlarged and short rhachis is called the *common receptacle.*

e. Many flower-clusters are branched or compound. The following are more common forms: —

1. Racemes may again be arranged in racemes, the clusters being branched or compound, thus producing *compound racemes.*
2. Similarly we may have *compound corymbs, compound umbels,* and *compound spikes.*
3. A loosely, more or less irregularly compound cluster is called a *panicle.*
4. A more compact cluster, in form and mode of division like a bunch of grapes, is called a *thyrsus.*

f. Apply these terms to the specimens in hand, and make diagrammatic sketches to illustrate each kind.

IV. Determinate Inflorescence.

Examine a fresh flower-cluster of cultivated Geranium in which some of the flowers are still in bud.

a. Notice that the *innermost* flowers, which correspond to the *uppermost* or *terminal* flowers in an elongated cluster, are the first to open. Hence the inflorescence is *determinate,* or *centrifugal.* Why *centrifugal?*

b. Select all the determinate flower-clusters from the specimens before you, and notice that these may also be divided into two groups: —

1. Those in which the flowers are *pedicellate.*
2. Those in which the flowers are *sessile.*

c. Of the pedicellate forms the following are the most common: —

1. The flowers in a loose cluster, more or less branching, but the terminal flower of each branch opening before the lateral flowers. A cluster of this kind, which may be of various shapes, is a *cyme.*
2. If the cyme is quite compact, and nearly flat-topped, it is a *fascicle.*
3. A loose, much-branched cyme is a *compound cyme.*

d. The more frequent forms with sessile flowers are the following: —

1. A compact, rounded cluster similar to the head, but centrifugal in inflorescence, called a *glomerule.*
2. A series of glomerules arranged in whorls in an interrupted, spike-like cluster called a *verticillaster.*

e. Apply these terms to the specimens before you, and make diagrammatic sketches of each kind.

V. Solitary Inflorescence.

Both indeterminate and determinate inflorescence may be *solitary,* and the flowers may be pedicellate or sessile. In the indeterminate kind the solitary flowers are remote, axillary, while in the determinate kind they terminate the main stem or branches.

If solitary flowers are pedicellate the stalk is called a *peduncle.*

VI. Mixed Inflorescence.

The two kinds of inflorescence are more or less mixed in the same compound flower-cluster, the order of inflorescence being in part indeterminate, and in part determinate.

Such inflorescence is *mixed.*

VII. Prepare an illustrated outline of all the terms employed in this lesson.

LESSON XVII.

The Flower.

Materials required: Fresh specimens of the Early Wake-robin (*Trillium nivale* Rid.)[1], in flower.

I. The Parts of the Flower.

Examine the flower, beginning with the outermost parts. Notice: —

a. The outermost whorl of the floral envelope, the *calyx*, consisting of three green, leaf-like bodies, the *sepals.*

b. The inner whorl of the floral envelope, the *corolla*, consisting of three white parts, larger than the sepals, called *petals.* The calyx and corolla together constitute the floral covering, or *perianth.*

[1] This is one of the earliest flowers to appear in the spring, but if this lesson is reached before fresh flowers can be collected, alcoholic specimens may be used; or, still better, the lesson may be adapted to the cultivated Geranium discussed in the following lesson.

Remove one petal and the two adjacent sepals without disturbing the remainder of the flower.

Observe : —

c. A whorl of six stalked, narrow, yellow bodies, called *stamens*, collectively forming the *andrœcium*. Remove one stamen, and note that it consists of two parts.

1. The white, smooth stalk, or *filament*.
2. The yellow, two-lobed body on the filament, called the *anther*.

Examine the anther carefully. If it is not too old, note : —

I. The green extension of the filament lying along one side of the anther, called the *connective*.

II. The two large yellow parallel lobes, or sacs, between which the connective lies, called the *cells* of the anther, each itself slightly longitudinally two-lobed.

III. The anther-cells, filled with a yellow, more or less cohesive substance, — the *pollen*.

Under the microscope this is shown to consist of nearly spherical, slightly roughened, minute bodies called *pollen-grains*.

IV. In an older anther notice that the anther-cells break, *dehisce*, longitudinally along the lines separating the two lobes of each cell, thus discharging the pollen.

d. Remove some of the stamens, and notice an enlarged body in the centre of the flower, terminating above in three slender arms. This is the *pistil*, or *gynœcium*. Make the following observations : —

1. Examine with a lens the upper (inner) surface of each of the three arms. Notice the rough, moist surface, the *stigmatic surface*, to which some pollen-grains probably adhere. How far down does this extend? That part of each arm bearing the stigmatic surface is a *stigma*.
2. Notice the green basal portions of the arms below the stigmas. Each is a *style*.
3. Notice the large green triangular basal portion of the pistil, — the *ovary*.

   This rests on the enlarged end of the peduncle, called the *receptacle*, or *torus*, to which the stamens, corolla, and calyx are also attached.

   With a sharp knife make a transverse section of the ovary near the middle. With a lens examine the interior of the ovary, and notice: —

I. The three compartments, *cells*, or *loculi*, separated by partitions, or *walls*.

II. In each one of the cells a number of small, roundish bodies, — the *ovules*. These are attached at the inner angle of each cell, on a ridge, or area, called the *placenta*.

   The arrangement of the ovules in the cell, i.e., their manner of attachment or distribution in the ovary, is called *placentation*.

III. Carefully examine a single ovule with a good lens, or, still better, with a compound microscope. Note that it consists of two parts: the main body of the ovule, and a short stalk, or *funiculus*, which is the free end of a much

longer stalk which lies against the body of the ovule, and is consolidated with it. (See Fig. 9 B 4.)

iv. Under favorable circumstances in sections specially prepared the following facts may be observed:—

The outer part of the ovule consists of one or two coats, perforated at the tip of the ovule (here turned back so as to be near the base) by a small opening, the *micropyle* (Fig. 9 B 5).

Within the walls, or coats, of the ovule lies the comparatively large *embryo-sac* (Fig. 9 B 2), in which is found, immediately under the micropyle, a small nucleated cell called the *oösphere* (Fig. 9 B 3), with which are associated other cells, the discussion of which cannot here be taken up to advantage.

II. The Physiology of the Flower.

For the proper comprehension of a flower, a study of the functions, or uses, of the several parts is necessary.

For this purpose we may conveniently divide the parts of the flower into two sets: *a*, the *essential organs*, the androecium and gynœcium; and *b*, the *non-essential* parts, the calyx and corolla.

a. The Essential Organs.

1. As may easily be seen, the ovary is the part which develops into the *fruit*, and the ovules develop into *seeds*. But the ovules will not so develop unless *fertilized*. This is accomplished by the pollen in the following manner:—

The pollen must first be deposited upon the moist stigmatic surface (Fig. 9 A 5), to which it readily adheres.

Each pollen-grain is a cell, with distinct cell-walls (Fig. 9 C 1), and a dense granular *nucleus* (Fig. 9 C 2) imbedded in the general cell-contents (Fig. 9 C 3).

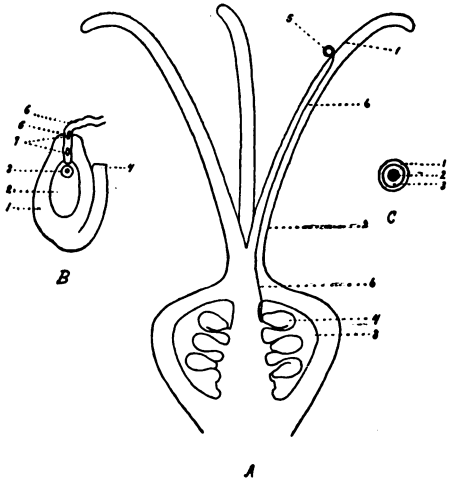

Fig. 9.

A. Longitudinal section of the ovary of *Trillium nivale* (magnified).

1, stigma; 2, style; 3, cell of the ovary; 4, ovule; 5, pollen-grain on the stigmatic surface; 6, pollen-tube entering the micropyle of the ovule below.

B. An ovule of same (magnified).

1, wall of the ovule; 2, embryo-sac; 3, oösphere with its nucleus; 4, funiculus; 5, micropyle; 6, pollen-tube entering the ovule; 7, nuclei.

C. Pollen-grain (magnified).

1, cell-wall; 2, nucleus; 3, general cell-contents.

Shortly after the pollen-grain has been deposited upon the stigmatic surface it germinates; i.e., the outer wall breaks, and the contents, including the nucleus, are pushed out in the form of a slender *pollen-tube* (Fig. 9 A 6).

This pollen-tube penetrates through the central, hollow, or soft, loose-celled portion of the style, into the cavity of the ovary, and enters the micropyle of the ovule, where the large special cell, the oösphere, awaits it (Fig. 9 A and B). By this time the nucleus has divided into several nuclei (Fig. 9 B 7); and when the pollen-tube comes in contact with the oösphere (Fig. 9 B 3), one of the nuclei unites with the oösphere, and the latter is *fertilized.*

The fertilized oösphere, or *oöspore* as it is now called, then grows by cell-division, developing into the embryo plantlet, with its cotyledon, plumule, and *radicle*, the embryonic stem and root combined, while the seed matures on the parent plant. In flowering plants the length of the pollen-tube varies with the length of the style; but in all of them the process of fertilization must be accomplished essentially as described above, or no seed will be produced.

2. It will be noticed that in this, and other flowers, the anthers are not usually in direct contact with the stigmatic surface, hence some external agency must carry the pollen from the anthers to the stigmas.

The agencies most frequently concerned in

this work are wind, water, and animals, notably insects.

The transfer of pollen from the anther to the stigma constitutes *pollination*, which in all cases must precede fertilization.

The various adaptations of the parts of the flower to pollination will be considered more fully in subsequent lessons.

b. The Non-essential Organs.

The calyx and corolla are not directly concerned in the production of seed, hence are not essential to the flower.

Their uses may be briefly stated as follows: —

1. They serve to protect the essential organs in the bud.
2. When fully developed they may, by their form, size, and position, protect the essential organs against rain, wind, and undesirable insect visitors.
3. By their bright colors they may serve to attract the attention of insects which are useful in the work of pollination; and their form, size, and arrangement may be such that insects of this kind will find a resting-place while at work.

The perianth, then, is chiefly of use in pollination, and as a protection to the essential organs.

LESSON XVIII.

The Morphology of the Flower.

Materials required: Fresh flowers of *Trillium nivale*, house Geranium, Fuchsia, Primrose, Pussy-willow,[1] and other accessible forms. Some should be in bud. Also a fresh flower of Cactus, a few Roses, and a Peony if it can be obtained.

Compare the flowers of Trillium, Geranium, Fuchsia, and Primrose, and observe the variation in the several sets of organs in the following order: —

I. THE CALYX.

Notice the variation in the following characters: —

a. Division. Note that the sepals of Trillium and Geranium are distinct, the calyx being *polysepalous*, while those of Fuchsia and Primrose are united, the calyx being *monosepalous*, or *gamosepalous*.

b. Number, form, color, texture, and surface of the sepals. Note that in these characters the sepals, or lobes, vary much as do leaves, the same terms being applicable to both.

II. THE COROLLA.

Observe the following characters: —

[1] If this is desired very early in the season, the flowers may be forced by putting twigs into water, and keeping them in a warm room for a few days. (See Appendix B.)

a. Division. The corolla, like the calyx, varies as to the separation of its parts, being *polypetalous* or *monopetalous* (*gamopetalous*). Note also the *tube* and *limb* in the corolla of the Primrose.

b. Number, form, color, texture, and surface of petals or lobes. — Compare the several forms, and note that in these characters the petals vary like sepals and leaves.

c. Form of the Corolla. The variations in the form of the corolla may be expressed by the following terms: *tubular, funnel-form, bell-shaped, labiate, salver-shaped, rotate, papilionaceous, ligulate, rosaceous, sac-shaped,* etc.[1] Name the forms of the corollas before you.

d. Position of the petals. Note that the petals of Trillium are attached to the torus; such are *hypogynous:* while those of Fuchsia are placed on the calyx, and are *perigynous.*

What is the position of the petals (or corolla) in the remaining flowers before you?

e. Length and position. Notice the relative length and position of the parts of the calyx and corolla in each flower.

f. Æstivation. The manner in which the sepals and petals are folded in bud is of interest, and is the *æstivation* of the flower. It may be *valvate, reduplicate, involute, imbricate, plicate,* or *supervolute.*

Observe the kinds of æstivation in the buds before you, and name each.

[1] For these and other terms in this lesson, see Glossary, Appendix D.

III. The Andrœcium.

Compare the stamens in the several flowers. Observe the variation in the following characters: —

a. Number and length of the stamens, and their position with reference to the parts of the corolla; i.e., *opposite* or *alternate.*

b. The insertion of the stamens. They may be *hypogynous, epipetalous, perigynous* or *epigynous.* Observe this in your specimens.

c. The union of stamens. In some of the flowers the stamens are free from each other, or *distinct.* In Geranium they are united by their filaments, being *monadelphous.* In other flowers they may be *diadelphous, triadelphous,* etc.

When united by their anthers stamens are *syngenesious.*

d. The anthers. Make the following observations: —

1. Compare their form, color, number of cells, and dehiscence.

   The dehiscence may be *longitudinal, transverse, valvate,* or *porous.*

2. Notice the attachment to the filament, the anther being *innate, adnate,* or *versatile.* When adnate, it is either *introrse* or *extrorse,* according as it faces inward or outward in dehiscence.

3. Compare the pollen of the several flowers with special reference to its *color* and *abundance.*

e. The filaments. Compare the length, form, surface, and color in the several forms.

IV. The Gynœcium.

Compare the corresponding parts of the pistils of the several flowers with each other as follows: —

a. Compare the *stigmas* and *styles* with special reference to *number, form, color, surface,* and *division,* using familiar terms such as were used for leaves, etc.

b. Compare the *ovaries.* Note: —

1. The *number, size, form,* and *surface* of the several kinds.

2. *The position of the ovary.* When free from the calyx it is *superior;* when wholly united with the calyx, so that it seems to project below it, it is *inferior;* and when partially united it is *half-superior* or *half-inferior.*

   Find these forms among your specimens.

3. Make transverse sections of the ovaries, and note the number of cells (*loculi*) and placentæ, and the number, form, and size of ovules in each.

   The placentæ are *parietal, axile,* or *free-central,* accordingly as the ovules are attached to the outer walls of the ovary, the inner angles formed by partitions, or *septa,* in a several-celled ovary, or on a central axis which is not united by septa with the outer walls.

c. As to *kind,* or *division,* pistils are classed as follows: —

1. If there is but one cell, one placenta, one style, and one stigma, the pistil consists of a single *carpel,* or *pistil-leaf,* and is a *simple pistil.*

2. If there are two or more cells, placentæ, styles, or stigmas, the pistil is made up of more than one carpel, and is *compound.*

V. THE TORUS.

The torus varies more or less in size and form, usually being simply the somewhat enlarged end of the pedicel or peduncle, but sometimes assuming other forms which may always be described in familiar terms.

The ovary is sometimes separated from the torus proper by a fleshy, usually variously lobed and colored body called the *disk.*

VI. Examine the flower of Trillium again.

a. Note that: —

1. It has both stamens and pistils, hence is *perfect.*
2. In addition to these, it also has both calyx and corolla, and is *complete.*
3. The sepals are equal in form and size, and are symmetrically placed around the centre of the flower. The same is true of each of the other sets of floral organs. Therefore the flower is *regular,* or *actinomorphic.*
4. The flower has all its parts in sets of *three,* or a multiple of three; there being *three* sepals, *three* petals, *six* stamens, and *three* carpels in the pistil. The arrangement of these parts is *alternate,* the petals alternating with the sepals: the outer set of three larger stamens with the petals; the smaller inner set of stamens with the outer set; and the three cells or angles of

the ovary with the inner stamens. (See *plan* of the flower, Fig. 10.)

A flower whose numerical plan is uniform throughout, and whose parts are regularly placed in alternating series, is said to be *symmetrical.*

A flower which is *complete, regular,* and *symmetrical* may for purposes of illustration be considered a *typical flower.* The flower of Trillium is practically a typical flower.

Fig. 10.

Plan of the flower of Trillium nivale.

Showing the number and relative position of the parts of the calyx, corolla, androecium, and gynœcium.

b. Compare the flowers of Geranium. They are *irregular (zygomorphic)* and *unsymmetrical.* Why?

c. Compare the flowers of the Pussy-willow. They are *imperfect* and *incomplete.* Why?

d. Draw plans of all the flowers before you.

VII. THE FLOWER A BRANCH.

The flower is a branch specially modified for reproductive purposes. That it is a branch is shown by the following facts: —

a. The flower is developed from buds, which are at first indistinguishable from leaf-buds, and which, like leaf-buds, are axillary or terminal. (See LESSON I.)

b. The parts of the flower are modified leaves.

1. That the parts of the floral envelope are leaves may often easily be seen.

   In the Cactus-flower, for example, there is usually a perfect gradation from the small, fleshy leaves through sepals to petals.

   Sepals and petals often resemble leaves in form and venation, and the former also in color and function, being often green chlorophyl-bearing organs.

2. The stamens and pistils, while usually very distinct from the perianth, are sometimes connected with it by intermediate forms. Thus in Roses, sometimes some of the stamens are partly developed into petals, while in very double ones *all* the stamens, and even some or all of the pistils, become petals. Other double flowers, such as the Peony, show the same thing. The structure of a stamen is not unlike that of a leaf. The filament corresponds to the petiole, the connective to the mid-rib, and the cells of the anther to the two halves of the blade.

   The structure of the pistil is also like that of a leaf folded and united at the edges. The style corresponds to the tapering apex, the tip of which forms the stigma.

The ovules are borne on the united edges which form the placenta.

The leaves, or carpels, when more than one, may be united in a variety of ways, as noticed in Sec. IV. of this lesson.

In fruit the carpel often spreads out, and assumes a leaf-like form.

3. All the parts of the flower sometimes revert to true leaves. In such cases a tuft or rosette of leaves appears instead of the flower. The Windflower, Strawberry, and other species furnish occasional illustrations.

4. In rare instances buds develop in the axils of parts of the flower, leafy branches or flowers growing out of the flower in such cases.

Flowers of the Jessamine and Rose sometimes furnish illustrations.[1]

LESSON XIX.

The Fruit and Seed.

Materials required: As noted under each subdivision of the lesson. Notice: —

1. *Flowers are produced for the purpose of developing fruit and seeds.*

[1] These special forms should be secured when obtainable, and either pressed, or preserved in alcohol.

2. *The matured ovary, with such other parts of the flower as become consolidated with it during the process of growth and ripening, forms the* FRUIT.
3. *The ripened, fertilized ovule is the* SEED.

The Fruit.

Examine the following series of fruits: dried fruits of Sunflower, Goosefoot, Corn, Maple, Hazel, Butternut, Marsh-marigold, Milkweed, Pea, Tick-trefoil, Tobacco, Jimson-weed, Lilac, Poppy, Purslane, Black Mustard, Shepherd's-purse; alcoholic specimens of fruits of Cherry (both young and mature), Gooseberry, Blackberry, Strawberry; Fresh fruits of Apple, Squash, and Orange.

These fruits are each the product of one flower.

A. Fruits developed from one Flower.

Notice that in a general way the fruits which are the product of one flower may be classed into two groups: those which do not open or *dehisce* regularly to discharge the seeds, called *indehiscent fruits*; those which dehisce regularly, usually along definite lines, called *dehiscent fruits.*

I. Indehiscent Fruits.

Separate the indehiscent fruits from the others. Notice that they vary much in form, size, etc.

Most of these indehiscent fruits are the product of a *single pistil*, a few only (those of the Rose, Blackberry, and Strawberry (See Lessons XXXIII. and XXXIV.) being developed from *several pistils* in the same flower. Note: —

a. Simple Fruits, — the product of single pistils. Of the indehiscent fruits produced from a single pistil, whether simple or compound, two general forms will be recognized: those in which the fruit dries in ripening; and those in which some part, or all, of the fruit becomes fleshy at maturity.

1. *Dry Fruits.* As a type of the dry fruits, take the fruit of the Sunflower, the so-called seed: —

   I. Make longitudinal and transverse sections, and notice that the fruit is one-celled and one-seeded, the matured wall of the ovary, the *pericarp,* being uniformly hard, and enclosing the seed, from which it separates easily. Such a fruit is an *achenium.*

   II. Compare the *utricle, nut, grain,* and *samara*[1] with the achenium, selecting specimens of each kind from the series of fruits.

2. Of the fruits which become fleshy at maturity, two classes are recognized: (*a*) those which contain a hard stone; and (*b*) those which are fleshy throughout.

(*a*). *Stone Fruits.* Take the cherry as a type.

   I. Notice that it is covered with an *epidermis,* within which lies the pulpy, fleshy part of the fruit, in which is imbedded the hard *stone.* Break the stone. What does it contain?

   Make a section through the middle of a young cherry. Notice that there is no hard

[1] See Glossary, Appendix D, for these and other terms in this lesson.

stone within, but, instead, a white fleshy layer, which almost insensibly grades into the pulpy part of the fruit. The epidermis — the fleshy part of the fruit — and the wall of the stone together form the *pericarp*, the seed being within the stone.

Such a fruit is a *drupe*.

II. Compare the Butternut, a *tryma*, with the drupe.

(*b*). *Fleshy Fruits, proper.* Make a section both ways through a Gooseberry.

I. Notice that the walls and septa of the ovary have become fleshy, the seeds being imbedded in the pulpy mass. Such a fruit is called a *berry*.

II. Compare the orange, *hesperidium ;* the squash, *pepo ;* and the apple, *pome*, with the berry.

b. Aggregated Fruits. These are indehiscent fruits produced by the consolidation of several pistils in one flower. Such are the Blackberry, Strawberry, and Rose-hip.

1. Study the Blackberry as a type. Notice that each of the pistils (of which there are several in one flower) has developed into a small drupe. The fruit formed by the union of the small drupes is sometimes called an *etærio*.

2. Compare the *Strawberry* and the *hip* of the Rose, additional forms of aggregated fruits, with the etærio.

II. Dehiscent Fruits.

These may be developed from simple or compound pistils. Notice that the dehiscence may take place in a variety of ways : —

a. In the fruits developed from simple pistils, as illustrated by the Milkweed, Pea, and Tick-trefoil, the dehiscence takes place either along *one* line, or *suture*, only, the fruit being a *follicle;* or along *two* opposite sutures, thus dividing the pericarp into two parts, or *valves*, the fruit being either a *legume* (Pea), or a *loment* (Tick-trefoil). Compare the two forms.

b. For types of dehiscent fruits which are developed from compound pistils, and generally called *capsules*, study the fruits of Tobacco, Jimson-weed, Lilac, Poppy, Purslane, Black Mustard, and Shepherd's-purse.

1. Notice that dehiscence takes place in one of the following ways: —

   I. The capsule may split along the septa, each one being divided, the dehiscence being *septicidal.*

   II. The capsule may split between the septa, each valve so formed bearing at the middle a septum when present. Such dehiscence is *loculicidal.*

   III. When in loculicidal dehiscence the valves in addition fall away from the septa, which usually remain united at the centre, the dehiscence is *septifragal.*

   IV. Dehiscence may also be *porous* and *circumcissile.*

Find all of these types among the specimens before you, and illustrate each kind by a diagram.

2. Examine the capsules, and notice the several kinds: —

I. Take the fruits of Tobacco, Jimson-weed, Lilac, and Poppy, as types of the true *capsule.* Note the difference in the size, surface, number of cells, and modes of dehiscence of the several forms. The number of cells in the fruit is not always the same as the number of cells in the ovary.

II. Compare with the true capsules the fruits of Black Mustard, Shepherd's-purse, and Purslane, types respectively of the *silique*, *silicle*, and *pyxis*, which are special or modified forms of the capsule.

B. Multiple Fruits.

Get alcoholic specimens of Mulberries, and fruits of Pineapple and Pine. As a type of the group study the Mulberry or Pineapple. The fruit really consists of a large number of small fruits united with each other, each of them the product of one flower. Such a fruit is called a *sorosis.* Compare with this the *strobile*, or *cone*, of the Pine.

The Seed.

Examine the seeds of the Bean, Pea, Apple, Sunflower, Corn, etc., which have been soaked in water. Make sections of the several seeds. Notice that: —

a. The seed is covered by one or two coats.[1]

The outer, or *testa*, is usually hard, and in some seeds is variously ornamented on the surface, being

[1] In the fruit of the Sunflower be careful not to mistake the pericarp for the seed-coats.

tuberculate, pitted, hairy, etc. The inner coat, when present, is usually thin and membranous.

The *embryo* consists of the *cotyledons, plumule,* and *radicle* (see LESSON VII., iv.), and is contained within the seed-coats, and either wholly occupies the space, or is imbedded in various ways in a quantity of nourishing matter which is called the *albumen.* Seeds like the latter are *albuminous,* like the former *ex-albuminous.*

In ex-albuminous seeds the nourishing matter is stored up in the fleshy cotyledons.

Dispersion of Fruits and Seeds.

In addition to the seeds and fruits already enumerated procure the following: Fruits of Balloon-vine, Thistle, Burdock, Spanish-needles; seeds of Catalpa.

In order that a young plant may properly develop, it is necessary that the seed from which it is to grow be removed some distance from the parent plant, which otherwise would interfere with its growth. This is accomplished in several ways, and in all cases the seed or fruit is modified in structure and form to aid in its transportation.

Fruits and seeds may be dispersed as follows: —

a. By water. In such cases the seed is protected by outer impervious and thickened light (porous) coats. See how many of the seeds and fruits will sink in water.

b. By wind. In such cases the seed or fruit is light and buoyant, either through inflation of the coats, or because of appendages, such as wings and hairs.

c. By animals. Animals transport seeds and fruits in a variety of ways:

1. The outer part of the fruit may be fleshy and palatable, as well as bright-colored and odorous, to attract animals.

   The seeds in such cases are either bitter or otherwise unpalatable, or they are enclosed in a hard shell or stone which makes them indigestible. They therefore escape destruction.

2. Other fruits and seeds are variously provided with hooks, spines, glands, etc., by which they adhere to the bodies of animals, and are thus carried about.

d. By hygroscopism. This results from the warping or unequal drying of fruits, which, when disturbed, burst suddenly and scatter the seeds.

Divide the seeds and fruits before you into groups, according to their manner of dispersion, and observe in each kind the special modifications which aid in its transportation.

LESSON XX.

The Wake-robin and the Lilies.

Materials required: Fresh specimens of the Early Wake-robin (*Trillium nivale* Rid.)[1] in flower and fruit. Similar specimens of Bellwort, Lily-of-the-valley, False

[1] Any other species of *Trillium* may be used, or the lesson may be commenced with any of the other species listed.

Solomon's-seal, Solomon's-seal, Asparagus, any true Lily (*Lilium*), Tulip, Dog-tooth Violet, Onion, Hyacinth.

A. The Wake-robin.

Examine the plant of the early Wake-robin in detail. Notice: —

I. The Plant as a Whole.

What can you say of its general appearance? Its size? Does it flower the first year? Note: —

a. The root and rootstock. The number, form, texture, and surface of the roots. Are they primary or secondary? Notice that they pass out from a short horizontal rootstock. Examine this carefully. How do you know that it is an underground stem? Describe its form, size, surface, etc. Note particularly its older, or posterior, extremity.

Observe that in older plants the rootstock often gives off one or two small branches, which appear like lateral buds.

b. The stem. Note its direction, texture, color, and surface.

Make a transverse section of the stem. What is its structure?

c. The leaves. Note their number and arrangement.

Study the parts of the leaf, — the venation, form, margin, apex, surface, etc.

If you have plants of a season, or rootstocks with the bud-like branches (see *a*) bearing leaves, compare their leaves with those of the ordinary flowering form of the plant.

II. THE INFLORESCENCE.

a. What is the position of the solitary flower? Is the inflorescence determinate or indeterminate? Note the length and direction of the peduncle.

b. Examine the flower. Is it perfect? Complete? Regular? Symmetrical?

Examine the parts in detail:

1. *The calyx.* Note the number, form, length, surface, color, of the sepals, as ascertained from the study of a number of flowers. Is there much variation in these characters?

2. *The corolla.* Describe the petals similarly. Note the insertion of the petals.

   Compare the length of petals and sepals.

3. *The andrœcium.* Note the number of stamens, their insertion, position with reference to other parts of the flower, etc. Describe a single stamen fully, noting the color, length, surface, and form of the filament; and the color, length, number of cells, dehiscence, attachment to filament, etc., of the anther. Also color and abundance of pollen.

4. *The gynœcium.*

   1. Review the characters of the pistil as determined in LESSONS XVII. and XVIII. Describe fully, noting, in addition to the characters already noticed, the form, color, surface, etc., of the parts of the pistil.

11. Examine the mature fruit. Note the number of cells and seeds; the character of the pericarp. What kind of a fruit is it? Describe the seeds, stating number, form, color, surface, etc.

5. *Pollination.* In a fully opened flower notice the relative position of the anthers and stigmas. Is self-fertilization possible? What do the white petals indicate with reference to the method of pollination? Do you find honey-glands? Is the flower odorous?

Consider also the meteorological conditions which prevail at the season of the year when this plant flowers; also the abundance of flower-visiting insects. Observe the flowers in the field on a bright day, and see if they are visited by insects. If so, note carefully the manner in which the insect enters the flower, and the parts of the flower with which it comes in contact. Examine the body of the insect also, and record the result of the observations.

What is the result of the insect's repeated visits to different flowers?

III. HABITAT AND DISTRIBUTION.

Note the general surroundings of the plants in their native haunts, the kind of soil in which they grow, etc.; i.e., their *habitat.*

This species is distributed in the region from Western Pennsylvania to Kentucky, thence west to Minnesota and Iowa.

Write a complete description of the plant, including pollination, habitat, and distribution, and make detail drawings of a leaf and the parts of the flower.

B. Related Species.

I. Compare the other species listed, giving special attention to the following characters : —

a. The plant, — its duration.

b. The stem, — its texture; kind of underground stem.

c. The leaves, — venation and margin.

d. The inflorescence, — are the flowers regular and symmetrical? What is the numerical plan of the flower? The number of cells in the ovary, and its position? Are the sepals and petals similar? Kinds of fruit, and number of seeds.

II. Classification.

a. The comparison shows that these species resemble each other in the following characters : —

They are perennial herbs. The flowers are regular and symmetrical, their parts being in threes. The fruit is a few or many seeded capsule or berry.

The leaves are entire, and parallel-veined, and the sepals and petals are alike.

The Wake-robin is unlike the remaining forms in the last two characters, hence it is not a typical representative of the group in which it is placed.

Plants possessing the enumerated characters are grouped together in the

ORDER LILIACEÆ.

The Lily Family.

b. Notice that the plants compared differ from each other chiefly in the arrangement and venation of the leaves, the division of the styles, and the kind of fruit. Minor differences in inflorescence and in the form, color, etc., of parts may also be observed.

The more important differences necessitate a division of the *Order* into groups, or *Families*, and each of these again, because of minor differences, is divided into *Genera*. In the following outline the genera (their names appearing in parenthesis) are indicated only by common examples.

The following key will serve sufficiently for purposes of recognition: —

ORDER LILIACEÆ.

Characters as given above.

A. *Leaves parallel-veined; sepals and petals similar.*

Family I. — *Liliaceæ*.

Style one; fruit a capsule.

The following belong to this family: —

Lilies (*Lilium*), Tulip (*Tulipa*), Dog-tooth Violet (*Erythronium*), Onion (*Allium*), Hyacinth (*Hyacinthus*).

Family II. — *Convallarineæ*.

Style one; fruit a berry.

The following belong here: —

Lily-of-the-valley (*Convallaria*), Solomon's-seal (*Pol-*

ygonatum), False Solomon's-seal (*Smilacina*), Asparagus (*Asparagus*).

Family III. — *Uvularieæ*.

Style three-cleft or three-parted; leaves broad, not grass-like.

The Bellwort (*Uvularia*) represents this family.

B. *Leaves netted-veined; sepals and petals not similar.*

Family IV. — *Trillieæ*.

Leaves whorled.

Represented by the Wake-robin (*Trillium*).

Our species is *Trillium nivale* Riddell.

Expand this outline, adding other characters, and make a comparison of the types of genera in each family.

III. Distribution and Economic Importance.

The plants of the Order *Liliaceæ* number about two thousand species, and are found in all climates.

The order is of great importance, the plants of economic interest being of three kinds: —

a. Food plants, — such as the Onion, Leek, Garlic, and Asparagus.

b. Medicinal plants, — such as *Aloe,* yielding Aloes; *Scilla,* yielding Squills; and Hellebore (*Veratrum*).

c. Ornamental plants, — such as Lily-of-the-valley (*Convallaria*), Crown Imperial (*Fritillaria*), Day Lily (*Hemerocallis*), Hyacinth (*Hyacinthus*), Lilies, many species of the genus *Lilium,* Tuberose (*Polianthes*), Tulip (*Tulipa*), several species of *Yucca,* etc.

Many of our finest cultivated plants belong to this order.

LESSON XXI.

The Soft Maple.

ACER DASYCARPUM EHRH.[1]

Materials required: Maple twigs in full bloom, either those caused to bloom in the house or from out-of-doors, the latter greatly to be preferred; pieces of Soft Maple wood convenient for examination; dry fruits of various Maples, as many varieties as may be obtainable; pressed leaves of several species. The pupils must also have access to a grove of Soft Maple trees, native or planted, or to a row along the street. Other species of Maple, if in the vicinity, should be pointed out.

I. A report by the pupils of what may be observed of the Soft Maple in early spring. Let each examine the trees, and present a written report of his observations in reference to various particulars, as the following: —

1. *The tree;* its height and diameter, its manner of growth related to its position and surroundings. Most trees about our homes have suffered more or less from pruning; what has resulted in the branching, for instance?
2. *The bark,* on stem, branches, twigs; how cast off from year to year?
3. *The wood,* its character, weight, color, etc.

[1] See note at the close of this Lesson.

4. *The economic value* of the tree; for what purposes used? Where found growing naturally? If planted, for what purposes? How far does it serve the purpose for which it is planted? Advantages and disadvantages as a street tree.

II. THE INFLORESCENCE.

Examine the supernumerary buds, noted before, and see to what they have developed, either in the warm air of the room or out-of-doors. Note: —

a. The abundant bloom-buds, their position on the twigs; on the tree as a whole. Notice that the bloom for the present season was all perfected last year; the warm airs of spring do no more than cause the buds to open. This was shown, though perhaps less strikingly, in the Lilac and the Cherry. Notice that in the present case the leaf-buds have not yet started. You will discover later that the inflorescence is all out of the way before the leaves make any start at all.

b. Examine a single bud. Note that the axis has lengthened a little, to set free the crowded structures which it bears; the bud-scales, few in number, the outer deciduous. The flowers, how many? How arranged?

c. The flower. Study the make-up of a single flower: the pedicel, long or short; the calyx, its lobes or divisions; the petals — ?; the stamens, number, different development in different flowers. What seems to be the condition of their perfect development? Does the place of the flowers on the tree have anything to do with the matter? In flowers where the stamens are

most perfectly developed is there any trace of a pistil? Flowers which produce stamens only, or in which the pistil, if present, remains undeveloped are designated — how? Find flowers in which the pistil has attained complete development. Are the stamens present in such flowers? Do they undergo development?

Study the pistil; its surface and style-arms under the lens.

Make with a sharp knife a transverse section. Find two loculi. How many ovules in each? Make a vertical section parallel to the plane of the style-arms. Notice the disk [1] on which the pistil rests, and from which the anthers spring. This disk is small, it is true, but is nevertheless interesting as distinguishing widely the whole series of plants, natural order, to which the Maple belongs.

III. Pollination.

How does the pollen pass from the anthers to the style-arms? Are there any peculiarities in the stamens or in the pollen itself that favor transportation by the wind? Are there in the style-arms any adaptations that render these organs specially fitted to the reception of wind-borne pollen? Do bees or similar insects visit the blooming Maples?

IV. The Fruit.

Note in dried specimens the two parts, the seed-case proper and the wing; the first hairy, the second veined. What purpose is subserved by the wing?

Compare several seeds. Notice that while some are

[1] This disk is seen in perfection in the flowers of *A. saccharinum*.

complete in themselves, others show plainly on one side the surface by which they were at one time attached to something else — another fruit? Perhaps such twin fruit is to be seen in the collection. These double fruits correspond to the two loculi of the pistil; and such a winged dry fruit in general is called a *sama'ra* (pl., *æ*). To see how the pistil with two loculi and several ovules passes into such a samara will require close watching during several weeks.

V. The Leaves.

These follow in this species the inflorescence. We may examine pressed specimens, comparing the venation and the marginal indentations.

VI. Classification.

If a Sugar or Hard Maple can be visited conveniently, let the pupils compare it as to particulars specified in I. 1, 2. Compare in class the leaves and fruits of the two Maples. Notice that both are *Maples*, have the same general type of fruit and leaf, and yet differ in the manner in which the idea of the fruit and leaf is expressed; for instance, in the matter of size, surface, texture, etc. These minor details mark different kinds, *species*, of Maple, Hard Maple and Soft Maple, we say. Popular opinion long ago distinguished these; and when science recognizes in the two trees two *species*, it does but confirm popular judgment. The word species is Latin. What is its original significance?

For reasons good and sufficient the scientific names of plants are written in Latin form, and in two parts; the first describing or designating the kind,

genus, the second the *species*, or special form of the kind. The specific name expresses an adjective relation. In the present case Maple is the name of the *genus*; Soft, the species; but in Latin we write, —

ACER DASYCARPUM EHRH.

and for the Hard Maple, —

ACER SACCHARINUM WANG.

After the specific name we write the initial or abbreviation of the name of the man who first applied to the plant the scientific name it bears; thus, *Ehrh.*, Ehrhart *L.*, Linnæus; *Mx.*, Michaux, etc.

There are in the United States several other species of *Acer*. Thus in the eastern part of the country we have *A. spicatum* Lam., a small but handsome tree, extending as far west as Iowa, and *A. pennsylvanicum* L. In the Mississippi Valley and eastward we have a tree, *A. rubrum* L., much resembling the species we have so carefully studied. In Utah and the West we have still another shrubby Maple or two, while on the Pacific coast we have a large-leafed large tree, *A. macrophyllum* Pursh, like our Soft Maple again. The genus *Acer*, accordingly, in the United States includes eight species, which may be grouped as follows: —

1. Large Trees.
   - *a.* Fruit smooth.
     - Flowers appearing with the leaves, *A. saccharinum* Wang.
     - Flowers appearing before the leaves, *A. rubrum* L.
   - *b.* Fruit rough.
     - Flowers later than the leaves, *A. macrophyllum* Pursh.
     - Flowers before the leaves, *A. dasycarpum* Ehrh.

2. Small trees, shrubs, one species even prostrate.
   - *a.* Flowers later than leaves.
     - Flowers in dense upright racemes. *A. spicatum* Lam.
     - Flowers in long drooping racemes, *A. pennsylvanicum* L.
   - *b.* Flowers with the leaves.
     - Leaves five- to seven-lobed, *A. circinatum* Pursh.
     - Leaves three- to five-lobed, *A. glabrum* Torr.

A. dasycarpum Ehrh., ranges from New Brunswick to Kansas, from the Great Lakes to Northern Florida.

The genus *Acer* is also represented in all parts of the Old World; south of the equator, however, in Java only.

NOTE. — In *North American Silva*, vol. ii. p. 97 and p. 103, the specific name *A. barbatum* Mx., is given for Hard Maple, and *A. saccharinum* L., for the Soft Maple. It is probable that under the "rules" some such nomenclature may at length be adopted. Since the changes have not yet, however, found place in our manuals, it has been thought best to retain the familiar designations, even at the risk of being esteemed too conservative.

LESSON XXII.

The Soft Maple. — *Reviewed.*

ACER DASYCARPUM EHRH.

Written Exercise.

AFTER working through the problem of so much of the structure and history of the Soft Maple as the preceding lesson has brought to light, let the pupil, by way of review, write a somewhat full description of

the Maple, a description containing his field-notes, and combining with these a discussion of facts brought out in the class-room. Such topics as the following may be discussed: —

I. The general character of the tree, its manner and rapidity of growth, as shown by the largest tree of the species to be found in the neighborhood.

II. The economic value of the tree.

a. As furnishing wood, lumber. What is curly or "Bird's-eye" Maple?

b. As planted for a wind-break. Consider the case of the farmers of the Mississippi valley.

c. As planted for shade, a street tree. Is it the most useful? What is the effect of pruning? Proper pruning?

III. *The Inflorescence*, its character and adaptation to wind-fertilization. Draw diagrams to illustrate the variety of flowers discovered, using as pattern the diagram on p. 76, Fig. 10.[1]

IV. The fruit, its adaptation to dispersal by the wind. Why should it be dispersed at all?[2] What position does the samara tend to assume in falling? Within a few weeks you may find the seeds germinating in every direction; does it seem that in planting the seeds of the Maple they should be covered deeply?

[1] In the diagram by dotted lines connect the united parts as in this case, the sepals. Mark the place of absent organs by a ×.

[2] See Lesson XIX.

LESSON XXIII.

The Willows.

SALIX — sp; sp.[1]

Materials required: The pupils must have access to Willows of various species if possible. In addition, there will be needed for comparison, wood-sections of as many species as possible; pressed specimens of leaves; dry fruits; twigs in various stages of inflorescence.

I. THE TREES OR SHRUBS.

The pupils may prepare, as before, a report upon the various features of the Willows to be studied, as seen in the field, noting size; mode of branching, branching as affected by trimming, polling, etc.; the nature of the twigs; the tough bark, the brittle wood.

II. THE INFLORESCENCE; "Pussy-willow Buds."

a. Its early appearance, in some species much earlier than in others. Does the growth begin before the frost is out of the ground?

b. The form of the inflorescence, the *catkins*. Note their position on the branches. In less advanced specimens, note the bud-scales which cover the catkins. How many are there? Note the gradual beautiful unfolding of the spicate clusters.

[1] The determination of species in the genus *Salix* is a matter of so much difficulty, that it is not thought best to be particular here. Any species will answer. But see Section VI. following.

c. The staminate catkins. Note the position of the flowers, their spirally whorled arrangement.

The individual flower: its position; its subtending bract, the margin and soft, silky pubescence; the stamens, their number, position, structure; the pollen, compare with the pollen of *Trillium*, *Acer*, as to quantity, dryness; the third body at the base of the filaments, the *nectar-gland*. At the tip of the nectar-gland find with the lens a minute droplet of nectar. Has it taste? Have the Willow flowers odor? Draw a staminate flower projected against its bract, all enlarged, say four times.

d. The pistillate catkin.

Note, as before, the arrangement of the flowers.

The individual flower: its pistil, its pedicel, surface; the style; the stigmatic lobes, their number and color; the nectar-gland. Draw the pistillate flower projected against its silky bract.

Note the number of loculi; in the mature fruit find the seeds. How are these distributed?

III. Fertilization.

How is the pollen distributed; borne from stamen to stigma? What special adaptations leading to this end? What is the purpose of the nectar-gland? What makes the flowers conspicuous in this case? Watch the blooming Willows on a sunny day, and note what is going on.

IV. Habitat.

In what localities do you find the Willows? In what places do they flourish best? How are they com-

monly planted? Try thrusting Willow twigs in spring into the moist ground, in some place where they may remain undisturbed. What happens? Do they grow if thrust in upside down. The Willow not only puts forth very readily branches on occasion, as when polled, from adventitious buds, but likewise puts out abundant roots, if circumstances favor, from any part of the stem.

V. Economic Importance.

For what are Willows useful in your neighborhood? Is the wood of any value?

VI. Distribution.

Willows are found in all parts of the Northern Hemisphere. There are perhaps one hundred and fifty species in all. While common everywhere by lakes and water-courses, they are yet by no means restricted to such localities. They sometimes affect arid regions, and make all altitudes their own. *Salix herbacea* L. is a tiny shrub. It clings to the rocks of the lofty Alps, is found on the summits of our own White Mountains, and extends its range far into the Arctic zone.

Perhaps the most common species in the Eastern United States are the following, here grouped according to the time of inflorescence: —

Flowers appearing before the leaves.	*Salix humilis* Marsh. *Salix tristis* Ait. *Salix discolor* Muhl.
Flowers with or after the leaves.	*Salix cordata* Muhl *Salix nigra* Marsh. Salix alba var. vitellina L. Salix fragilis L.

The first two species are found in dry places, hillsides, etc.; the last two are not rare in cultivation. *S. alba vitellina* has yellow twigs in spring.

LESSON XXIV

The Aspens.

POPULUS TREMULOIDES MX.
POPULUS GRANDIDENTATA MX.
POPULUS MONILIFERA AITON.
POPULUS ALBA LINN.

Materials required: The pupils are to have access to any or all the species named, Quaking Asp, Aspen, Cottonwood, Silver-tree. Other materials, as heretofore, — pressed leaves, wood-sections, dry fruits, twigs of any or all the species in various phases of bloom. The trees generally bloom in the order of the list. The process, however, may in any case be hastened by keeping the twigs a few days in the warm air of the school-room.

I. The Trees.

Whatever the species, the tree is to be described, compared, or contrasted in all particulars with *Salix*. Note especially the nodulose branches, the leaf-scars, the bud-scale scars. On old trees of some species of *Populus* (*P. monilifera*) the bud-scale rings can be counted back six or eight years. Observe that the twigs, branchlets, are quite as deciduous sometimes as are the leaves. Many of the round, seal-like scars result from the abscission not of leaves, but of twigs.

You may find branchlets ready for such separation, and note the ease with which they are detached. How may you in any case distinguish twig-scars from leaf-scars? In vigorous young trees of *P. monilifera* the twigs are sometimes "winged;" i.e., bear ridges of corky bark running lengthwise. Compare the bark of any *Populus* with that of *Salix*. Both contain a very bitter alkaloid, *salicin*. Taste the inner bark of any species.

II. THE INFLORESCENCE.

a. Appears before the leaves in all the native species.

b. The general form of the inflorescence to be studied as before. Note the bud-scales which cover the catkins; their number, shape, surface, viscid in some species (*P. monilifera*). The peculiar resin which varnishes sometimes leaf-buds as well as flower-buds has a pleasant balsamic odor, which suggested for *P. balsamifera* its popular designation, "Balm of Gilead" tree. Of what service may this resin be to the tree?

c. The staminate catkin.

Compare in all particulars with the correspondent structures in *Salix* species. Note especially the number of stamens, the light, dry pollen, and the absence of nectar-glands. Sketch the staminate flower, as seen in vertical radial section, to show the relative position of bract and stamens. Draw a single bract as seen from without.

d. The pistillate catkin.

Note the exposure of the stigmas by the slowly ex-

panding ament, so that the whole, with its flexible axis, is like a single flower.

For the individual flower, find the subtending bract, early deciduous; note its laciniate margin. Observe the disk or receptacle which here half encloses the base of the ovary, simulates a calyx; the lobate stigma. Draw the pistillate flower.

III. FERTILIZATION.

How effected in *Populus?* Note the differences in adaptation as compared with *Salix* species. Note the differences in adaptation in trees or plants, all of which, nevertheless, appeal to one and the same agency. Thus, compare *Populus, Acer, Ulmus.*

IV. CLASSIFICATION.

In what respects do *Populus* and *Salix* differ? In what particulars agree?

At least three native species of *Populus* are common in the United States east of the Missouri River, and these three are easily distinguished. Thus: —

1. Bud-scales resinous; stigma-lobes broad; bracts glabrous; bark rough, — *P. monilifera* AITON.

2. Bud-scales not viscid; stigma-lobes linear; bracts silky; bark smoothish, —

a. Bud-scales smooth, shiny; bracts long, silky; bark whitish; leaves finely crenate-dentate; tree less symmetrical, — *P. tremuloides* MX.

b. Bud-scales and bracts short, silky; bark greenish, or on older trunks greenish-brown or yellowish; trees larger; leaves coarsely crenate-dentate, — *P. grandidentata* MX.

V. HABITAT.

Note the conditions under which your particular species grows, its surroundings, etc.

VI. ECONOMIC IMPORTANCE.

For what purpose is the wood of this species used? of other species? For what purposes are species of *Populus* planted? Notice that the variety of lumber known as poplar does not come from any species of *Populus*. Poplar lumber is made from *Liriodendron tulipifera*, a southern tree sometimes called poplar, but better designated as the Tulip-tree.

LESSON XXV.

The American Elm.

ULMUS AMERICANA LINN.

Materials required: The pupils shall have free access to trees of the species. Besides this are required a sufficient number of blooming twigs, pressed leaves from the year preceding, several good wood-sections, showing both transverse and vertical faces; dry fruit in abundance.

I. FIELD REPORT.

1. The Tree.

Let the pupils present written reports of what they have been able to observe concerning the tree as it stands, — its habits of growth; mode of branching;

shape as determined by surroundings; height; diameter; whatever can be ascertained as to age.

2. The Bark.

Compare the bark on the main stem; the branches; twigs; how cast off from the main stem? Exactly as in the Soft Maple? Find twigs of successive years' development, — one year old; two; three. About how much does the tree add to its height year by year?

3. The Wood.

Note its character; weight, color, strength, rapidity of growth. What is the average annual increase in diameter? In which years is this increase greater, earlier or later?

4. The Economic Value of the Tree.

If found growing naturally, for what purpose is the timber used? If planted, for what purpose? What of the value of the Elm as a street tree? Has the Elm any advantages here?

II. The Inflorescence.

a. On a twig breaking into bloom, find two sorts of buds, bloom-buds and leaf-buds. Which develop first? Note the direction assumed by the flower-bud as it unfolds.

b. A single bud. Notice the bud-scales; their arrangement. Compare the arrangement of the scales with that of the buds, remembering how bud-scales stand related to leaves, and these, in position, to buds. Sketch a half-open bud to show the arrangement of the scales.

In each of the scales (inner) find two parts; that developed last year; its color; the growing part below. Push back the lightly adherent (deciduous) scales, and expose: —

c. The flower-clusters. Where are these produced? Note the minute brown bractlets. Some of these doubtless represent the *stipules*, which belong to the bud-scales (leaves). Note the scars left where the bud-scales break off.

d. A single flower. Note the pedicel, its length, the joint or node near the middle; the calyx, its color, form, lobes. Sketch a flower as it appears under the Coddington, to show pedicel and calyx.

The *andrœcium.* Note the number of the stamens and their attachment; the filaments; anther-lobes. Find out, if possible, how the pollen is discharged, and note its character.

Do you find stamens and pistils in the same flower? Study the pistil, noting its form, color; the bifid stigma; the beautiful white crest of cilia which surmounts the style-arms. Draw the pistil as seen from the side.

Make a cross-section of the ovary; how many loculi are there? How many ovules? Compare the mature fruit, noting the changes that have occurred in passing from flower to fruit. Draw a samara.

e. Pollination. By what agency is the pollen deposited on the style-arms? Are there any special adaptations to pollination by the agency of the wind — in the anthers? the pollen? the style-arms? In the

time of inflorescence? Compare in all these particulars what has been learned about the Maple.

f. The fruit.

Note the date of blooming of the Elm flowers, and watch for the formation of the mature fruit. This will presently come drifting abundantly to the ground, when pupils may note whether or not the tree has as yet put forth its leaves.

g. The foliage.

This may be studied later, when the tree is in full leaf, or pressed leaves may be made the subject of critical examination. Note especially the form and venation of the leaf as indicated. Study the obliquity of the leaf-base as related to the position and direction the leaf assumes upon the twig. Are there stipules? Draw a single leaf, natural size.

h. Distribution.

Is the American Elm a common tree? It is purely an American tree, and has a wide range extending from Newfoundland to the Black Hills of South Dakota, and south to Florida and Texas.

LESSON XXVI.

The Slippery Elm.

ULMUS FULVA MX.

Materials required: Leaves, fruit, wood-sections of Slippery Elm. Flowering twigs in various stages of development. Slippery Elm bark from the druggist.

Let the pupils compare in all accessible particulars with *U. americana.* If a Slippery Elm can be visited, of course, so much the better.

1. Compare the two trees in habit; mode of branching; bark; wood; flower-buds, their development, scales.

2. Let the pupil make out a list of particulars in which the species agree; in which they differ. Note that the differences are mainly superficial, difference in detail; in general plan of flowers and fruit and leaves the trees are alike. If one is an Elm, so is the other. They are simply different species of Elm. Notice that science here again simply confirms popular judgment, gives more exact definition to forms which all men perceive. "Science is applied common-sense."

3. *Geographical Distribution.*

Ulmus fulva is not uncommon in the Mississippi Valley, but is by no means so familiar a tree as is *U. americana.* It ranges almost over the entire wooded region of eastern North America, from Maine to Dakota, south to northern Florida and Texas.

4. *Economic Value.*

For what purposes is the wood of the Slippery Elm used? For what is the bark esteemed valuable?

LESSON XXVII.

The Elm Family and the Order of which it forms a Part.

Materials required: Herbarium specimens and pressed leaves of:—

Ulmus americana L.	White Elm.
Ulmus fulva Mx.	Slippery Elm.
Ulmus racemosa Thomas.	Rock Elm.
Ulmus alata Mx.	Winged Elm.
Celtis occidentalis L.	Hackberry.
Cannabis sativa L.	Hemp.
Humulus lupulus L.	Hop-vine.
Maclura aurantiaca Nutt.	Osage-orange.
Urtica dioica L., or *Laportea canadensis.*	Stinging Nettle.
Pilea pumila Gray.	Richweed.

Dry fruit of all these species so far as obtainable.

Wood-sections of all the arboreous species, to show bark, wood, etc.

We have already studied two species of Elm,— *U. americana* and *U. fulva.* On comparing the leaves and fruits of these two with the other leaves and fruits before us, we can readily see that in our whole list we have nothing else very much like the Elms. The *Celtis* in foliage is perhaps nearest. Compare, however, especially the venation. Compare also the wood of the Hackberry, and the bark with the same structures in the Elms.

In Kentucky, and farther south, however, we find a tree whose leaves, though small, are almost exactly like those of the Elm. The fruit, too, is a simple akene like the central part of the Elm fruit, the wing omitted. This Southern tree is called Planer's-tree, *Planera aquatica* Gmelin. This tree, with the Elms in our list, all of which extend as far west as Iowa, make up the Elm Family, the *Ulmeæ*.

Now take up the fruit, wood, and leaves of *Celtis*. In all our series we shall find nothing just like *Celtis*. The fruit is, however, like the other fruits; it is a one-seeded nutlet or akene. Wherein does it differ from the fruits of species of Ulmus? Is this an essential difference? Can you see that in both trees, the Elm and the Hackberry, the outside of the fruit, its covering merely, is modified to the accomplishment of the same general purpose? Compare carefully the wood and bark of *Celtis* with other wood-sections. The differences you have discovered are deemed sufficient to separate *Celtis* not only from any one of the Elms, for instance, but from all of them; and so we put *Celtis* in a family by itself, — the Hackberry Family, *Celtideæ*.

By similar comparisons we group the Hemp and the Hop into the Family *Cannabineæ;* the Nettle and Richweed into the Family *Urticeæ;* while the Osage-orange, with its milky juice, shining leaves, and aggregated fruits, stands off by itself — rather, joins hands with the Mulberry, *Morus rubra*, common in some parts of the country — to make still another group or family, the *Moreæ*.

We may now better appreciate all this if we arrange

our knowledge in definite order. Write the families one after the other by name. After each family name place in order the names of the genera making up the family as here represented, and after each genus enter the species composing it. You will thus have a table something like that on pages 96 and 97.

To the families already named we may add yet a fifth, some of the members of which we know by name at least, — the Family *Artocarpeæ*, which includes not only the Breadfruit-tree, *Artocarpus incisa*, but all the Fig-trees as well, and many of the India-rubber trees. The dry fig with which we are familiar does not much remind us of the fruits now before us, but we must note that here also each single seed represents a single flower; the fleshy part of the fig is the enlarged receptacle. Add, therefore, the Family *Artocarpeæ* to your list.

Now, all these families agree in certain general particulars: thus, they all have *stipulate leaves;* they have a regular *calyx, free from the* ovary, with *stamens as many* as the *lobes of the calyx*, and *opposite* these; in all the fruit is one-seeded (a single seed), differing only in the various modifications for insuring dispersal. All these families are accordingly grouped together to form the natural

ORDER URTICACEÆ.

named, strange as it may seem, from one of its most insignificant members, *Urtica*, the Nettle.

So the Elm belongs to the Nettle order, and the Hackberry, the Hemp plant, and the Hop-vine, the Mulberry and the Fig, to say nothing of the scores of less

significant plants represented by the Richweeds and Nettles. What a motley array! One would think at first sight that the association of forms so diverse would be irrational, the very reverse of system or classification; and yet we plainly see that all these various plants have flowers alike, in all the fruit is just the same, whatever its disguise. Here, as elsewhere, the old law holds good, "Ye shall know them by their fruits." Our plants differ chiefly in what we may term habit. Some take a longer, some a shorter, time in which to bring forth fruit; some are therefore annual, some perennial. Some stand erect; others find access to better air and sunlight by climbing upon stems of neighboring plants. Some produce fruit to be scattered by the passing winds; others recognize the existence of hungry animals in the world, and furnish fruit which these will bear about and scatter.

LESSON XXVIII

The Box Elder.

NEGUNDO ACEROIDES MŒNCH.[1]

Materials required: Flowering twigs of the Box Elder; flowering twigs also of the Hard Maple, if obtain-

[1] Linnæus called the Box Elder, a Maple, and named it *Acer negundo*. Later its generic distinction was recognized by Mœnch, and the name changed to *Negundo aceroides* Mœnch. In *Garden and Forest*, iv. 166, Mr. Sudworth gives reasons for retaining Mœnch's generic name, but returns to the specific name first applied by Linnæus, and calls the tree *Negundo negundo* (L.) Sudw.

able, for comparison. The pupils are, as usual, expected, if not to procure the requisite material, at least to visit and study the trees. Dry fruit is also desirable for comparison; wood-sections, herbarium specimens of foliage, etc., as heretofore.

I. Let the pupil compare the Box Elder with any species of Maple in the particulars following: —

1. In general appearance; mode of growth; branching; color of twigs; buds, their smoothness or pubescence; the bark on the main stem. Can the Box Elder be recognized at sight at any season of the year?

2. In Inflorescence.

In *Negundo* note the time of appearance of flowers as compared with foliage. Compare especially with *A. dasycarpum* and *A. saccharinum*. Note the style of the inflorescence in the Box Elder, its origin and type. The staminate flowers of Box Elder and of Hard Maple agree in what particulars? How about the pistillate flowers in the same plants? Note especially the arrangement of the flowers in *Negundo*. In the same flowers observe the incipient wings. The pistillate raceme terminates a shoot; the staminate flowers do not terminate the branchlets on which they rise. Compare twigs on which last year's fruit may still be hanging, and observe the effect of fruit-bearing on the branchlet.

In the flowers of *A. saccharinum*, note the *disk* to which reference has already been made (LESSON XXI., p. 94). Sketch a single fertile flower of *Negundo* to show the wings, and a flower of *Acer saccharinum*, if

obtainable, to show the disk. Each may be shown magnified four or five times.

3. In adaptations for pollen-dispersal, compare especially Box Elder and Hard Maple.

4. In Foliage.

Are the leaves in the Box Elder and the Maple of the same general type? Can you think of a Box Elder leaf as in any way correspondent to a Maple leaf part for part?

5. In Economic Importance.

What is the chief economic importance of *Negundo aceroides* in the part of the country where you are studying it? Do you know whether it is a tree of greater value in other sections? What trees make habitable the prairies of the western Mississippi valley?

II. Distribution.

The Box Elder has a remarkable distribution. It is one of the most widely distributed trees of North America. It extends from Vermont to California, and ranges from Winnipeg to Florida, Texas, and New Mexico. The centre of distribution where the tree attains greatest diameter and height is the eastern Mississippi valley. Towards the West the tree varies by having the bud-scales, and to less extent the leaves and fruit, more and more pubescent, until in California the winter-buds are fairly tomentose. Nevertheless, all the Box Elders of North America are included in one species, since between the smoothest forms of the East, and the most tomentose of the West, every intervening gradation may be shown. There is, therefore, only one species of *Ne-*

gundo in the New World, and, strange to say, only one other species in the whole world; this is in Japan!

Genus *Negundo* { *N. aceroides* Mœnch. / *N. japonicum.*

LESSON XXIX.

The Bur Oak.

QUERCUS MACROCARPA MX.

Materials required: Herbarium specimens of leaves; acorns with their cups; flowering twigs; wood-sections. The pupils, as usual, to have access to trees of the species studied; the fruit of other species of Oak, as large a series as possible. Hazelnuts, Beechnuts, Chestnuts, Ironwood fruits, all with the husk, or involucre, are indispensable for comparison. Wood-sections of other species are also most desirable for the same purpose.

I. THE TREE.

a. Let the pupil present a written description of the tree, with statement of all his observations in regard to it.

b. Study the wood-sections. Note the heartwood; the white wood. Compare the hardness, strength, and grain of this wood with that of the Maple, for example. What is known of the uses to which Bur Oak wood is applied?

II. THE FOLIAGE.

Describe the leaves; notice their peculiar outline,

venation, surface above, below. Sketch a leaf to show outline and venation. The venation of the oak leaf is very characteristic. Notice the stipules, very deciduous.

III. The Inflorescence.

a. Note the time of its appearance as regards the appearance of the leaves: *diclinous;* i.e., pistils and stamens are in different flowers; *monœcious,* on the same tree, though separate.

b. The staminate flowers. Note the form of the cluster, an *ament;* note the point from which the staminate cluster springs.

Notice the individual flower, its attachment, its envelopes, stamens; their number.

c. The pistillate flower, its position, structure, stigmas, style, ovary. Is there any trace of calyx? Make a smooth section of the pistillate flower, and note the number of cells in the ovary, and of ovules in each cell. Notice the numerous bractlets making up the involucre. Draw the section enlarged about six or eight times. A similar section of a pistillate flower should be examined three or four weeks later.

IV. The Fruit.

a. Take the dry acorns; note the "cup," involucre, made up of an indefinite number of bracts whose free tips give to the organ its bur-like character. Measure the extreme diameter of the largest bur you can find.

b. The acorn. Note its form, surface, color, apex, base. Sketch the acorn in its cup.

c. The embryo. With a penknife remove the cover-

ing of the acorn, the ripened wall of the ovary. How many ovules do you find? Where are the others? Perhaps near the base of the embryo you may find rudiments representing undeveloped ovules. Of the embryo, note the large, thick cotyledons, adhering at one point only. Make a vertical longitudinal section at right angles to the plane surface of the cotyledon. At the point where the cotyledons are joined, find the plumule. Only the radicle perhaps can be made out until after the seed has begun to grow.

d. Germination.

The manner in which the acorn germinates is most interesting. By searching under the blooming trees plenty of sprouting acorns can usually be found. Study these if possible, and sketch some of the more striking phases, illustrating the manner in which the plumule reaches the light of day. Compare the germination with that of the Bean. (LESSON VII., IV.)

V. Any other oak can be studied instead of the Bur Oak. Whatever be the species available, with it compare other species, using as a basis of comparison acorns and leaves. With a little practice many species can be distinguished by their acorns only.

VI. CLASSIFICATION.

a. Compare with the fruit of the Oak that of the Chestnut, the Beech, the Hazel. Note the variety in the character of the involucre. With the fruit of the Hazel compare the nutlets of *Carpinus* (Water Beech) and Ostrya (Ironwood), if these can be obtained.

b. If possible, compare the same plants in flower.

c. By such comparison we gain the idea of relationship as in no other way. The plants referred to make up the

ORDER CUPULIFERÆ.

the *cup-bearers;* and the oak, with its acorn, a nut borne in a cup-shaped involucre, is the *type.* In all cases this single nut comes from a compound ovary; i.e., from an ovary having several cells, and several ovules in each cell. All but one cell and one ovule are abortive, come to nothing.[1] In all cases the flowers are monœcious, and the leaves alternate, stipulate, and straight-veined.

d. The Oaks likely to be met with in the Eastern United States are: —

1.	*Quercus macrocarpa* Mx	Bur Oak.
2.	*Quercus alba* L.	White Oak.
3.	*Quercus muhlenbergii* Engelm.	Yellow Oak.
4.	*Quercus rubra* L.	Red Oak.
5.	*Quercus coccinea* Wang.	Scarlet Oak.
6.	*Quercus imbricaria* Mx.	Laurel Oak.

The first two are White Oaks; the lobes of the leaves rounded, never bristle-tipped.

The third has leaves almost like those of the Chestnut, — undivided, but sharply toothed.

The fourth and fifth are Black Oaks. The lobes of the leaves are bristle-pointed, and the acorns take *two years* to mature. *Q. imbricaria* Mx. has entire leaves and a globose acorn.

[1] Did any one ever find a "double" hazelnut? What does that mean?

e. A week or two after the blooming of the Oaks, the Hickories and Walnuts are available for study. To the Oaks they are closely related; and it will be interesting even at this point to compare their fruits, to trace so far the relationship.

VII. ECONOMIC VALUE.

a. Take the order *Cupuliferæ* throughout, and what do you say as to its economic importance? Let pupils write out a list of purposes for which oak-timber is used; for which it is best. What is the duty of our people in reference to the forests of Oak and Hickory and Walnut that still form so large a part of the natural wealth of our country? Is it wise to exterminate the forest?

b. Write a list of all the forest trees with which you are acquainted, and pick out the six that are of greatest value for lumber.

LESSON XXX.

The Shepherd's-purse.

CAPSELLA BURSA-PASTORIS MŒNCH.

Materials required: Fresh plants from the garden or field. The plant is a most common weed. Specimens may be brought in *entire;* the roots, carefully lifted and thoroughly washed, must be kept moist until studied.

I. THE PLANT; GENERAL DESCRIPTION.

Note its wholly herbaceous character; almost every

part above ground is green, and to that extent plays the part of foliage. Notice the quickness with which the plant in spring reaches perfection and fruit. Compare in this respect with plants already studied; *Trillium*, for instance.

a. Note the central axis: ascending, the green stem; descending, the white root. Each bears abundant branches. Wherein, however, does the stem differ from the root?

b. Take a plant that has been taken from the ground so carefully that its roots, even the smallest, are yet unbroken; float the roots out carefully in water in a glass dish over some dark surface, and examine.

Note the irregular, systemless branching, the uncertain origin of the rootlets; they seem to spring as occasion offers or requires from any place on the root-axis. Observe the great length of some of the slender rootlets, their swollen tips, near the tips minute root-hairs like soft white cotton fibres. These root-hairs, though seemingly insignificant, are really for the plant most important organs; they absorb from the soil much of the inorganic stuff which the plant uses continually for the development of its tissues.

With sharp knife or razor cut the root-axis squarely off, and note its structure under your lens: the hard woody central cylinder; the softer spongy cortex, easily stripped off; the indistinct epidermis; the woody cylinder of each secondary root continuous with that of the central axis.

c. The Stem.

Notice its surface characters, longitudinal markings; its branches, of two sorts, — those bearing flowers, *pedicels*, leafless; those which bear foliage, and repeat in all particulars the characters of the central stem. Where do the leafy branches take their rise? The pedicels? The fact that the pedicels here are without subtending bracts or leaves is reckoned surprising, and is a peculiarity of *Capsella* and its relatives.

Make a smooth cross-section of the stem, and with the Coddington make out the exogenous structure, pith, woody cylinder, epidermis.

Make a vertical section in the same way through a branch-bearing node; note that the structures of branch and stem are correspondent. Draw a diagram to illustrate this fact.

d. The Leaf.

Study the leaves of the *Capsella* in the various particulars already enumerated in LESSONS XI.–XV. Note the differences between the radical leaves and those borne at the nodes of the ascending axis. Try to determine the spiral arrangement of the stem-leaves and the fraction which expresses their angular divergence.

Note the more or less abundant plant-hairs, *trichomes*, to be found on the leaves and various parts of the plant: (1) simple, these more common about the flowers and upper parts of the plant; (2) stellately branching, abundant at the leaf-bases, etc. Sketch a few as they appear under the lens. Sketch what you esteem a typical leaf, showing the venation on one side at least, and the relation of the veins to the marginal indentations and teeth.

II. THE INFLORESCENCE.

a. Note the type of the inflorescence; the flowers open in order from without, below, upward, toward the centre, forming a corymbose, later a racemose, cluster. (See LESSON XVI.) Find flowers and fruit, therefore, of all ages on the same developing axis.

b. The individual flower.

Identify the successive sets of organs, and note the number of each. Write a brief description of the flower as outlined on p. 87. Notice that while the sepals are four, the petals four, the stamens are six, and the carpels but two. Notice also that the stamens are in two sets, of two sizes, two pairs long, and a pair of single shorter ones. How are the stamens placed with reference to each other and to the glands alternating with the stamen filaments? How many such glands do you find in one flower? Their function is not apparent.

III. FERTILIZATION.

Are these little flowers fertilized each by its own pollen? Compare the height of the long stamens with that of the pistil. Can pollen from the shorter stamens reach the stigma without extraneous assistance? Has any one observed insects visiting the flowers? Müller found that flowers reared under cover in such way that insects had no access to them were yet perfectly fertile.[1]

IV. THE FRUIT.

a. Pluck off the floral envelopes carefully, and on the receptacle with the lens find the minute green pistil.

[1] See Müller's "Fertilization of Flowers," p. 100.

Notice the median ridge down each flat face of the latter. Notice the form of the young pistil, and compare with the form of the same organ at the time when the petals are most fully expanded; when all the floral organs except the pistil have fallen.

b. Sketch each extreme phase of the pistil, enlarged sufficiently to show details.

c. We remember that a flower is a modification of a branch with its appendages, the floral organs standing in the place of leaves. In the flower before us, therefore, the fore-shortened branch bears the representatives of sixteen leaves.

We may perhaps best understand the case by considering that the floral organs are arranged in whorls of two.[1]

d. Make a smooth cross-section of the fruit, and with the lens find the transverse partition separating the carpels. If the fruit-pod be ripe enough, the two carpels, valves, may be pulled apart, leaving the brown seeds attached to the persisting partition.

e. Make now a diagram of the flower (See Fig. 10, p. 76) to show the relative position of the various floral organs at the time when the petals are fully expanded.

V. CLASSIFICATION.

The relatives of *Capsella* are numerous and common. Here belong: —

The Radish, *Raphanus sativus* Linn.
The Horseradish, *Nasturtium armoracia* Fries.

[1] See Gray's "Structural Botany," p. 206.

The Peppergrass,	*Lepidium virginicum* Linn.
The Watercress,	*Nasturtium officinale* R. Br.
The Turnip,	*Brassica rapa* Linn.
The Cabbage,	*Brassica oleracea* Linn.

Proceed to comparison among these as soon as opportunity offers. It will be soon discovered that all agree in many special particulars. For instance, all are *herbaceous* plants, and all have that *pungent sap* which we recognize in its sharpness in Horseradish. All have *four-parted* flowers, almost exactly in every case like those of *Capsella*, differing chiefly in size or color. All have the *same pod-like fruit*, although showing great variety in form. Plants having these general characters as constant features make up the Natural

ORDER CRUCIFERÆ.

All the plants mentioned, and many more like them, are Crucifers. What is the etymology and primary significance of that name? Is it here happily applied?

LESSON XXXI.

Buttercups and Windflowers.

Materials required: Specimens of the Creeping Buttercup (*Ranunculus repens* L.)[1] in flower and fruit. Similar specimens of the Windflower, Wood-anemone,

[1] *R. septentrionalis* Poir., or *R. fascicularis* Muhl., will answer quite as well.

Rue-anemone, Liver-leaf, Larkspur, Columbine, Marsh-marigold, Isopyrum, Baneberry, etc.

A. The Creeping Buttercup.

Study the Creeping Buttercup. Notice: —

I. The Plant.

What can you say of its general appearance, habit of growth, and duration? Observe: —

a. The root.

The number and mode of division or branching of the roots. Are they primary or secondary? Do they proceed from an underground stem? What is their texture?

In a rather old plant examine the centre of the cluster of roots. Do you find any which seem to be dead, nothing but the empty outer coat remaining? What is the significance of this?

b. The stem.

Notice the texture of the stem, and its structure as shown in cross-section. Describe its form, branching, surface, etc. Compare the stems of the earlier plants with those of older ones. What differences do you observe?

c. The leaf.

Notice the general structure of the leaf. Are all the parts of a typical leaf present? Note its venation, division, form, margin, etc. Notice that some of the leaves proceed from the root, are radical leaves, while others are cauline.

Compare the two kinds of leaves.

II. THE INFLORESCENCE.

Examine the flower-cluster.

a. Notice the distribution of the flowers on the stem. What is the order of inflorescence? Are the flowers solitary or clustered?

b. Examine a single flower. Is it perfect? Complete? Symmetrical? Regular? Examine the parts of the flower in detail:

1. *The calyx.* Note the number, form, length, surface, color, and other characters of the sepals. Are these characters constant in all the flowers? Is the position of the sepals the same in flowers of all ages?

2. *The corolla.* Describe the petals similarly. How are they placed with reference to the sepals? How do they compare with the sepals in form and size? What is their insertion?

Examine a single petal. Note the little scale at its base. Carefully examine this. Note that it covers a small pit, or pocket, — the *honey-gland.* Examine its contents, tasting them if possible. Draw, to show this scale, a single petal.

3. *The andrœcium.* Note the number of stamens; their insertion; their length and position with reference to the remaining parts of the flower. Describe a single stamen, noting the length, color, and surface of the filament, and the size, color, number of cells, and dehiscence of the anther; also the color and abundance of the pollen.

4. *The gynœcium.*

I. Note the number of pistils. Is each one simple or compound? Describe the parts fully, noting the placentation, number of cells and ovules in the ovary, and the form, color, surface, etc., of all the parts.

II. Examine the fruit. What kind of fruit is it? Do the pistils of the flower unite to form an aggregated fruit? How many cells and seeds are there? Is the fruit dehiscent? Describe the seeds, stating number, form, color, surface, etc.

III. POLLINATION.

Observe the relative position of the anthers and stigmas in a fully opened flower. Is self-fertilization possible? What does the bright-colored corolla, with honey-glands at base of petals, indicate? Are the flowers odorous? What is the character of the pollen? Is it dry and powdery, or sticky? If possible, examine flowers in the field, and observe if they are visited by insects. If so, describe in detail the manner in which the insect alights on the flower, and its behavior while there.

IV. GENERAL OBSERVATIONS.

What is the habitat of this species? When does it begin to flower? and how long does it continue? How soon after flowering does the fruit mature?

B. RELATED SPECIES.

I. Compare the other species mentioned in the list, with special reference to the following characters: —

a. The plant, — its duration.

b. The stem, — its structure and its juice.

c. The leaves, — their division, venation, and presence or absence of parts.

d. Individual flowers, — their numerical plan and general structure; the presence or absence of parts; the number of stamens or pistils.

e. The fruits, — kinds, and number of cells and seeds in each.

II. CLASSIFICATION.

a. Notice that all the species resemble each other in the following characters: All (or nearly all) are herbs with colorless juice. The flowers in all are polypetalous or apetalous, when apetalous the calyx being corolla-like; their parts all hypogynous; the stamens and pistils mostly numerous and distinct. The fruits are all one-celled, and mostly one or few seeded, being akenes, follicles, or berries. The leaves are usually more or less cut, without stipules, and mostly alternate or radical.

All plants possessing these characters belong to the

ORDER RANUNCULACEÆ.

b. Observe the differences between the several plants.

Notice that the Virgin's-bower (*Clematis*) differs from all the other plants in having all leaves opposite, and from most of the series by the tailed achenia (i.e., with feathery styles persisting in fruit), and four sepals

and no petals. This plant belongs to the Tribe CLEMATIDEÆ, thus set off from its relatives.

The remaining forms may be grouped according to the fruit into two additional tribes,[1] those with achenia like the Buttercups (*Ranunculus*), Windflower (*Anemone*), Liver-leaf (*Hepatica*), Rue-anemone (*Anemonella*), Meadow-rue (*Thalictrum*), forming the Tribe ANEMONEÆ; and those in which the fruit is a follicle, or berry, forming the Tribe HELLEBOREÆ. Those having follicles are Marsh-marigold (*Caltha*), *Isopyrum*, Columbine (*Aquilegia*), Larkspur (*Delphinium*), and Peony (*Pæonia*); while the Baneberry (*Actæa*) produces berries.

Each of these tribes is again subdivided into groups, or *genera*, differing from each other mostly in the character of the leaves, number of parts of the flower, and inflorescence.

The following key will assist in recognizing the genera: —

A. FRUITS ACHENIA.

TRIBE I. CLEMATIDEÆ. — Leaves all opposite. Achenia many, tailed.

Genus 1. *Clematis*. — Mostly climbing by petioles.

TRIBE II. ANEMONEÆ. — Herbs, not climbing. Leaves mostly alternate.

a. Petals none.

Genus 2. *Anemone*. — Involucre of leaves remote from flower; pistils very many; peduncles one-flowered.

[1] A greater number of tribes is usually recognized, but for practical purposes the subdivisions here recognized will be sufficient.

Genus 3. *Hepatica.* — Involucre close to flower, calyx-like; peduncles one-flowered.

Genus 4. *Anemonella.* — Peduncles umbellate, one-flowered; achenia several, ribbed.

Genus 5. *Thalictrum.* — Flowers panicled, often dicœcious; achenia few.

b. Petals and sepals both present.

Genus 6. *Ranunculus.* — Petals five, yellow or white, each with a honey-gland.

B. Fruits Follicles or Berries.

Tribe III. Helleboreæ. — Leaves alternate.

a. Fruits follicles.

Genus 7. *Isopyrum.* — Flowers apetalous, white; leaves compound.

Genus 8. *Caltha.* — Flowers apetalous, yellow; leaves simple.

Genus 9. *Aquilegia.* — Flowers complete; petals each with spur; flowers regular.

Genus 10. *Delphinium.* — Flowers complete, irregular, upper sepal spurred.

Genus 11. *Pœonia.* — Flowers large, mostly double by cultivation; pistils imbedded in fleshy disk.

b. Fruits berries.

Genus 12. *Actœa.* — Flowers in short racemes.

Expand this outline by adding other characters in which the plants before you differ.

III. Distribution and Economic Importance.

This order contains about five hundred species of plants, most of them in temperate and cold regions.

Most of the plants possess an acrid juice, which is sometimes poisonous.

Many of the species were formerly used in medicine,

but Aconite and Hellebore are the only important ones now used by physicians.

Many ornamental plants commonly cultivated in gardens belong to this order. Among these may be mentioned the Columbines (*Aquilegia*), Virgin's-bower (*Clematis*), Larkspur (*Delphinium*), Love-in-a-mist (*Nigella*), Peony (*Pæonia*), Globeflower (*Trollius*), etc.

LESSON XXXII.

The Dandelion.

TARAXACUM OFFICINALE WEBER.

Materials required: The pupils may furnish themselves with fresh plants in sufficient quantities. Care must be taken to secure plants quite entire, roots and all. If studied before the fruit has had time to ripen, akenes from previous years may be shown. A microscopic slide to show the milk-tubes is also helpful.

I. THE FORM OF THE PLANT.

a. Note the entire absence of the usual stem; the leaves appear to spring directly from the root. The fact seems to be that the internodes of the stem remain undeveloped, so that root and stem are consolidated. Such plants are described as *acaulescent*, stemless. Note the abundant milky, bitter, resinous sap in all parts.

b. The foliage. Note the form of the leaves; their origin below the surface of the ground, as if the root

in its downward growth had pulled the leaves after it. Stretch the leaf out smooth, and sketch its outline, at least on one side.

c. The root.

Note its length, its irregular branching, the numerous rootlets. If the specimen has been lifted carefully from the ground, the smaller rootlets will be found clothed with root-hairs near the tips, just as in *Capsella.* Notice that at each broken tip a drop of milk coagulates, and closes the wound. The milk is probably also protective in other ways; taste it. Such milk in plants is called *latex;* from such latex in Rubber-trees comes India-rubber, caoutchouc.

Make a thin cross-section of a larger root, and note the woody axis, the spongy cortex, the thin epidermis; the woody axis of each rootlet continuous with that of the main root, as in *Capsella.*

Note the persistence of the root; perhaps you can find out how long the plant endures. Is it annual, biennial, or perennial?

II. The Inflorescence.

a. Note the succession of flower-buds. In a large plant you may find them of all ages: the *tomentum,* wool, by which the buds are always protected; the *scape,* which by elongating carries the flowers aloft, — erect in the morning, what position does it assume later in the day? What position when the flowers have wilted? When the fruit matures?

b. Study now the unfolded bud. It seems to be the flower. Of what is it made up? Look with your lens,

and find scores of small flowers, *florets*, each with stamens, pistil, and corolla at the least.

Cut the whole structure vertically through the centre, and see that the florets all stand on the flat, widened end of the scape, the *disk*. Such an arrangement of florets upon a receptacle or disk constitutes a *head*. Note that the florets are developed, come to perfection from the centre outwardly; that is, the inflorescence of the head is centrifugal. Sometimes the process of inflorescence (blooming) does not in one day pass from circumference to centre of the head. Mark in the field such a head, and see whether it opens more than once to the completion of the floral development.

c. What seems to be the flower of the Dandelion is therefore not a flower at all, but a collection of flowers; and what seems to be the green calyx on the outside is not a calyx, since it surrounds not a single flower, but a flower-cluster. The seeming calyx is a circle of bracts forming what is called the *involucre*. In some plants which have such an involucre as this of the Dandelion, there is below the involucre a regular gradation to be seen between the ordinary foliage-leaf and the bract of the involucre. In the Dandelion the branch which bears the flowers, the scape, bears no foliage-leaves. The bracts of the involucre, *scales*, are accordingly quite distinct in form from any of the leaves, "well differentiated."

Notice the transition from the outer bracts of the involucre to colored corollas of the florets. Observe that the scales of the involucre are in two rows. Are there any scales upon the disk, amid the flowers?

d. The floret.

Take from the disk a single floret, and, holding it on a needle-point, examine it with your lens. The following organs can readily be made out: —

1. The calyx. Recognizable by its position, outside the other organs, adherent, blent with the ovary below, and there indistinguishable; above, frayed into fine white silken hairs, the *pappus*.
2. The corolla. Note its color; its form, a tube below, monopetalous, extended above to form a long, strap-shaped, petal-like organ. Note the notches at the tip of each corolla.
3. The stamens. Note their number; their tips may be counted in the unopened flowers at the centre of the disk, their filaments in flowers further developed; their coherence by their anthers, so that these form a straight tube (*syngenesious*); their dehiscence; the nature of the pollen.
4. The pistil; its simple ovary, long style, recurving style-arms (or branches), which bear the stigmatic surface on their inner faces. Note the several positions occupied by the style at different stages of the anthesis (blooming); at first below the level of the anther-ring, then emerging, showing the anthers as a collar, at length with a cleft summit, the arms slowly recurving. Sketch these three phases of the floret.

LESSON XXXIII.

The Dandelion. — *Continued.*

TARAXACUM OFFICINALE WEBER.

Materials required: As in the preceding lesson. To these add *Erigeron bellidifolium*, Fleabane, if obtainable; pressed flowers of the Dahlia, Sunflower, Aster, etc. The disk of a large Sunflower from which the seeds have fallen will be instructive. Flowers from any cultivated species of the order *Compositæ* may afford further material for comparison; fresh leaves of Lettuce, to show milky juice, etc.

I. Peculiarities in the Inflorescence of the Dandelion. Note: —

1. That the flower-cluster is indeterminate; that it corresponds to a raceme in fact, and may be regarded as a flower-cluster not different from that in *Capsella*, except that all pedicels and internodes are left undeveloped, and all the flowers appear in and on one and the same plane, the disk.

2. That the circumstances and conditions in which the florets are developed, and under which they act, explain many of their peculiarities.

a. The whole flower-cluster simulates a single flower. So perfect is the ruse, that not insects only, but even men, are deceived, to the great majority of whom the cluster is a flower. The involucre plays the *rôle* of calyx, and the rays make up the rest. The botanists

early recognized the true state of the case, but unfortunately called the head compound (composed of simple flowers), and gave to the Dandelion order the name COMPOSITÆ (compound). In many of the *Compositæ* the resemblance of the head entire to the form of some simple flower is rendered more striking still by reserving to only the marginal flowers the form of a ray (*ray-flowers*), which then simulate petals, while the much reduced central florets, *disk flowers*, make up often a differently colored centre. The Sunflower, even a dry specimen, shows this well. Compare, when convenient, the Marigold, the Daisy, the Aster. The common Fleabane, *Erigeron bellidifolium*, can perhaps be collected in the fields, and will afford interesting comparisons in color, shape, etc.

b. The place of the calyx, the usual protective envelop of the flower, being thus supplied by the involucre, protective envelop once for all for all the flowers, the function of the real calyxes is gone. The calyx of each floret is left, therefore, either to disappear, unnecessary and unnourished, or to remain on the condition of assuming some new function. Shut from exposure to the light, it becomes white and thin; its margin, poorly nourished, frays out into the delicate plumes of a parachute, and we have at last in the pappus a new organ (made out of an old one), an organ for the dispersal of the ripened seeds.

c. Chaff among the florets.

By cutting a Dahlia or Sunflower directly through the middle, vertically, it will be seen that associated with

the florets on the disk, there is still another set of organs to which we should give heed. Behind (toward the margin) each floret stands a simple bract, pale or colorless as the calyx, and for the same reason. These bracts constitute the so-called *chaff* of the disk. Each represents the leaf in the axil of which the flower is produced. We have seen that the flower is a modified branch, the branch an expanded bud. The bud appears normally in the axil of a leaf; hence we expect that a flower will be always backed or subtended by a bract or foliar organ of some kind. In the *Compositæ* these bracts are more or less suppressed, become mere rudiments, or, as in the Dandelion, disappear altogether.

II. The Pollination of the Dandelion Florets.

The Dandelion is fertilized almost exclusively by the aid of insects. Watch on any sunny day, and note the bees and other insects crawling upon the flowers. How does this effect pollination? What are the special adaptations to prevent self-fertilization; i.e., to prevent any particular floret from being fertilized by its own pollen? What is the final position of the style-arms? and what bearing does this have upon the problem?[1]

In the composite arrangement of flowers, is there any economy (1) of energy on the part of the plant? (2) of time on the part of the insect? Is the Dandelion a bad weed? Has it any advantages over other plants in the struggle for place, existence, on the earth?

[1] See Gray's "Botanical Text Book," Structural Botany, p. 222, sec. 411.

III. Relatives of the Dandelion.

In most composites the flowers are differentiated, as in the Sunflower. There are tubular disk-flowers and strap-shaped marginal- or ray-flowers. A few, however, like the Dandelion, have strap-shaped flowers only, and constitute its nearest relatives. Among these are Lettuce (*Lactuca sativa*), Salsify (*Tragopogon porrifolius* L.), Chicory (*Cichorium intybus* L.); and, strange to say, all these, and all of their group, have milky juice. Composites of the Sunflower type are, however, far more numerous. Indeed, in most parts of the country the autumn flora is very largely made up of Sunflowers and their kin, the Asters, Goldenrods, Thistles, Daisies, Mayweeds, Ragweeds, Burdocks, etc., — the world is full of them!

Our native *Compositæ* are accordingly divided for convenience into two groups; thus: —

Florets, at least those of the disk, tubular, —

Tubuliflorœ.

Types the Sunflower, Daisy, Goldenrod, etc.

Florets all strap-shaped, juice milky, —

Ligulatiflorœ.

Type the Dandelion, etc.

For the identification of the species of the *Compositæ*, recourse must now be had to some convenient manual; but in every case you may recognize a member of the order by the conjunction of these two characters: —

1. *Flowers gathered to form a head.*
2. *Anthers syngensious.*

LESSON XXXIV.

Apples, Plums, and Cherries.

PYRUS MALUS L., *PRUNUS DOMESTICA* L., *AND PRUNUS CERASUS* L.

Materials required: Apple, Plum, and Cherry branches in full bloom; wood-sections of the same species; similar sections also of Thorn-apple, Crab, Wild Cherry; seeds of Peach, Almond, Plum, Apricot, Nectarine; Rose-hips; herbarium specimens of the Wild Rose.

I. GENERAL DESCRIPTION.

a. Let the pupil bring in a written report of what he is able to observe concerning the fruit-trees in bloom; their mode of branching; the bark, its thickness, surface characters, and decadence; the vigor of the trees in neighboring gardens and orchards.

b. Compare all the wood-sections available. Note the differences in the grain of the wood; its rapidity of growth as indicated by the annual rings. Learn to recognize the different species by the appearance of the wood or bark.

II. THE INFLORESCENCE.

a. Its abundance; time in reference to the appearance of the leaves.

b. The individual flower.

Notice not the various sets of organs alone, their numbers, colors, shapes, etc., but especially their peculi-

arities, as of position or adhesion. Where are the petals attached? The numerous unequal stamens? Observe the position of the pistil or pistils, one in the Cherry, five in the Apple; in both cases inserted in the disk, a hollow receptacle continuous with the branchlet, and lining the calyx, consolidated with it. Notice that in the Cherry or Plum the calyx remains distinct from the ovary; in the Apple the calyx coheres with the several pistils. This results in the formation of two widely different types of fruit. Compare an Apple and a Cherry.

III. The Foliage.

The arrangement of the leaves has already been discussed, Lesson II., II., *f*. Note here, in addition to form, texture, surface, etc., the slender stipules, especially in the Apple, so slight as to be easily overlooked and quickly deciduous. Look for stipules on the leaves of the Rose-bush. Compare the venation of the leaves of the Cherry and Apple; the lower surfaces of the same leaves.

IV. The Pollination of the Flowers.

a. Here there is no doubt as to the agency by which the pollen is carried. Let the pupil report what he may observe, comparing all accessible fruit-trees on a sunny day. Capture some of the bees from the trees, and with a lens examine their legs and bodies.

b. What attractions are offered by the trees (Apple, Plum, etc.) to induce insects to visit the flowers? Enumerate at least three.

V. CLASSIFICATION.

a. In what respects do all the species compared agree? Which agree more closely, — Plums and Apples, or Plums and Cherries? Compare the seeds of Cherries, Plums, Apricots, Nectarines, Almonds, and Peaches. As compared with Apples, Service Berries, etc., these make a group or *Tribe* by themselves, — the PRUNEÆ; while Apples, Thorn-apples, Crab-apples, etc., make up the POMEÆ.

b. Now study the Rose-hips. Observe that these also have essentially the same structure as the young apple, except that the carpels do not coalesce with the receptacle; otherwise we should have an apple with many single-seeded carpels. If you can compare a Wild Rose, you will discover that in the floral arrangement the Wild Rose agrees in all particulars with the Apple bloom. Still, the Rose-hip is not an Apple; so we make it the type of still a third group, — the ROSEÆ.

c. Draw a diagram of the apple-blossom.

d. How the various tribes of rose-like plants are united together to form a natural ORDER will appear in our next lesson.

LESSON XXXV.

The Strawberry.

FRAGARIA VIRGINIANA EHRH, or
FRAGARIA VESCA LINN.

Materials required: Plants of the wild or cultivated Strawberry in flower; herbarium specimens (fresh speci-

mens are better) of *Geum album* Gmelin, or *Potentilla canadensis* L., *Rosa blanda;* a few Dandelion roots and *Negundo* twigs.

I. General Description.

a. Note the threefold structure, — roots, stem, and leaves. The stem, subterranean. Make a smooth cross-section of the stem, and compare with similar sections of the Dandelion root, the Box Elder shoot, and see what evidence you can find from the standpoint of structure that the Strawberry rhizoma is really a stem. What other evidences of stem-nature does the rhizome present?

b. Note the various sorts of roots presented by the plant, — the long fibrous roots of last year, the new roots of the season.

c. The "runners," branches. Observe their origin, function. Draw a diagram to show how such branches serve to reproduce the plant.

II. The Foliage.

Compare the leaves of the Strawberry with those of the Rose, part by part. In the Strawberry leaves, note the pubescence of petioles, and the lower surface of the leaflets; the venation in relation to marginal indentations.

III. Inflorescence.

a. Its type. Which flower in the cluster blooms first? How does the process of anthesis compare with that of *Capsella?*

b. The individual flower.

With the lens look the flower full in the face, and note its successive whorls, calyx, corolla, stamens, pistils. Note the accessory bractlets behind the calyx.

Now with a razor make a vertical section of the flower, and observe the insertion, attachment of the several organs.

Compare in all these particulars with what has been observed in the Apple, the Rose. Aside from the *habit* of growth, the chief difference between the Strawberry and the Rose lies in the form of the disk: in the Strawberry the form of the disk is convex; and it becomes at length the globose berry, over the surface of which we find the scattered seeds, fruits (the ripened pistils).

IV. FERTILIZATION.

How is pollination effected? In some cultivated Strawberries the flowers are dicœcious, or at least monœcious; and provision must be made in the planting for fertilization, or no fruit is produced. Confer with your gardener on this point.

V. AS TO CLASSIFICATION.

a. From our studies in SECTION III., it is plain, as we knew before by experience, the Strawberry is not a Rose, though very near it. In fact, it is the type of a kind of Roses. Compare now specimens of *Geum album* Gmel., or *Potentilla canadensis* L., both very common white-flowered weeds, very like Strawberries, though failing to ripen in the same way the disk. These herbaceous rose-like plants make up the Strawberry group or family, the FRAGARIEÆ.

b. In a similar way we may study the Blackberry (*Rubus villosus*), and the Raspberry (*Rubus idæus*), when these come to bloom, and find their Rose characters and their common peculiarities as well. In the Blackberry not only does the disk (receptacle) become pulpy, but the outer carpel in each case as well, as in the Cherry. In the Raspberry the outer part of the carpel only, while the torus (receptacle) remains unaltered. The Blackberry and Raspberry, accordingly, with their clustered drupaceous fruits, make still another section of the Roses, — the RUBEÆ.

c. We may now bring together all these several groups, tribes, or families of Rose-like plants into one, the

ORDER ROSACEÆ.

of which the principal characters are: —

1. Flowers regular; stamens borne on the calyx; pistils distinct, or in the *Pomeæ* united with the calyx-tube.

2. Leaves alternate and stipulate.

LESSON XXXVI.

The Roses. — *Review.*

ROSACEÆ.

LET each pupil write an essay on the order ROSACEÆ, dwelling especially on such particulars as the following: —

a. The structural (morphological) peculiarities which distinguish all rosaceous plants, as illustrated by the plants recently reviewed.

b. The economic importance of the order.

c. What is the purpose of what is popularly called fruit? For example, why does the Plum produce its sweet, juicy drupe, the Strawberry its luscious pulp, the Rose its scarlet urns?

d. Compare with the Wild Rose any of our cultivated forms. What is a double rose? What becomes of stamens, etc., when the rose becomes very "double"?

Has any one seen a *green rose?* How is such a flower to be explained? Perhaps some one has found among cultivated roses a branch which seemed to grow *through* the flower, and bore leaves, possibly a second rose beyond the first; what is the significance of such a freak? Compare always the relation of a flower to a bud, and a bud to a branch.

LESSON XXXVII.

The Wild Violet.

VIOLA PALMATA L. VAR. *CUCULLATA* GRAY.

Materials required: A sufficient quantity of plants of the species, roots and all, the roots clean-washed, and all kept moist until used; Pansy flowers and plants in sufficient numbers for comparison, if convenient; herbarium specimens of the species, with dry fruits and seeds.

I. General Description.

Compare with the plant last studied, *Fragaria.* Notice the short rootstock, stem; the roots and rootlets; the leaves.

II. The Foliage.

Study the form of the leaf, — its inrolled base lends the scientific, specific name; the parts of the leaf. Are there any stipules as in the Roses? Sketch an expanded leaf (flattened out), the blade wider than long.

III. The Inflorescence.

a. Observe that flowers of two sorts are present, — open, conspicuous blue flowers, and inconspicuous bud-like flowers that, by their smallness, are apt to be overlooked. Sometimes, too, they are developed somewhat tardily, later in the season. These bud-like blossoms are called *cleistogamous* flowers.[1] They may claim attention later on.

b. Note the origin of the flowers, borne singly on scapes or branches. Does the scape itself bear any evidence of being a branch? Of course the branch is here extremely specialized, and must not be expected to wear too many ordinary branch-features. Note the flexure of the scape above, so that the flower turns entirely over backwards, becomes *resupinate.*

c. The individual flower of the ordinary open sort.

1. Notice its general form; the lack of radial symmetry. Does the flower possess symmetry at all? Hold the flower facing you. Imagine it

[1] See Gray's "Botanical Text Book," Structural Botany, p. 241.

cleft by a vertical plane passing between the two upper petals. The flower will be divided throughout into two exactly similar parts. Can you in the same way pass other planes through the flower to divide it into similar parts? How would the case be with the Strawberry-bloom or the Apple-blossom? Flowers which admit of symmetrical division by one plane only are said to have bilateral symmetry, are *zygomorphic* (literally, yoke-shaped); while flowers which, like the Rose and the Apple-blossom, have radial symmetry are called *actinomorphic* (rayed).

2. Study the shape of the various parts: the sepals; the paired petals; the odd petal; the stamens, their coherence and dehiscence, on two of them appendages extending backward into the spur, or sac, of the odd petal. What happens when these appendages are pressed from below? The pistil; its general form, style, the open stigma, its direction.

d. The cleistogamous flowers.

These are so small as to afford some difficulty in investigation. They lie low down, and may be discovered of all ages, from mere rudiments to ripened pods. The entire absence of anything like petals will be usually a sufficient criterion for identification. In flowers of medium size the fact of fertilization can be discovered by examining with the Coddington a vertical section through the pod. The pollen-tubes can be seen

easily, like cobweb threads passing from the style downwards among the ovules.[1]

IV. FERTILIZATION.

Consider the problem in the light of facts already brought out. Do insects visit the colored flowers? Have any of the conspicuous flowers left pods, so far as can be seen? As a means of subsequent identification, tie yarn about the pedicels in some cases, and see how the problem results.[2]

V. Compare in all particulars the common Pansy if obtainable. Any species other than that first studied may be used for review.

VI. DISTRIBUTION.

Violets in one form or another occur over nearly the whole world; even the genus *Viola* is nearly cosmopolitan. Our species, var. *cucullata* Gray, seems to be common over the whole country, from Maine to California. Other familiar species are: —

The Common Yellow Violet,	*V. pubescens* Aiton.
The English Violet,	*V. odorata* Linn.
The Pansy,	*V. tricolor* Linn.

[1] Read Darwin's chapter on this subject, Forms of Flowers, p. 310.

[2] In addition to references already given, see *Müller's* "Fertilization of Flowers," pp. 117–121.

LESSON XXXVIII.

The Scotch Pine.

PINUS SYLVESTRIS LINN.

Materials required: The pupils are to have access to one or more trees, which must be studied about the time of blooming.[1]

For the laboratory provide short branch-tips, to show foliage, buds, etc.; wood-sections a few inches across, to show bark and wood-structure, rate of increase in thickness, etc.

I. THE TREES.

Let the pupils visit the tree, or trees, and report on such particulars as the following: —

a. The tree itself; its size, form, mode of branching. Compare in the latter particular the branching of trees heretofore studied. Notice in the Pine the continued indefinite upward extension of the central stem. Compare other evergreens, as the Spruce. Study the arrangement of the buds, and find out how the stem maintains its ascendancy among the branches. Could one determine approximately the tree's age by the whorls of branches? Can you determine (approximately) the annual increase in height? Such a stem as this of the

[1] The time of inflorescence varies with the seasons; in the latitude of Iowa, not far from June 1. The time of inflorescence is short. The tree must be watched, in order to observe its various phases. The present lesson may be studied just before the tree blooms.

Pine is called *excurrent*, as distinguished from the fashion of the Elm, for example, which is described as *deliquescent*. These terms are of Latin origin; are they appropriate?

b. The bark.

Note the bark on the trunk of the oldest tree to which you have access; follow up to the branches, noting the transition from strong, rough scales to papery layers, quickly deciduous; the green bark under the latter, more easily seen on branches, say, one inch in diameter: on the twigs find with the lens regularly disposed scales (scale-leaves).

c. The twigs.

Note their extension in length; the terminal bud; the bud-scales, scale-leaves, the latter of two parts; bud-scale scars of successive years; the method of branch-development, (1) in a foliage branch, (2) a branch bearing stamens, (3) in the branch which bears the cone of the season; the very short twigs or branchlets that bear the green foliage. Note that these fall off at length, and leave what appear like leaf-scars.

d. The foliage.

1. The green conspicuous portion, made up of "needles," each a leaf; how many needles in a cluster? borne on the short branchlets only. Examine a single needle; note the shape, color, apex, margin; examine with a lens, and find lines of minute openings, *stomata*. Note the twist in the mature leaves; compare young leaves on the branch of the season; note that

the leaves are all soft at base, the growing part. Make a thin section; examine with the lens, and find a white centre the only vein; resin-ducts. Pull a pair of leaves apart, and find (sometimes) a tiny bud between. Might there be more leaves? Notice that the leaves face each other, and incline to stand edgewise to the stem. Notice the sheath about the base of the leaves; the numerous papery bracts that make it up. Draw a pair of leaves with their sheath. Compare the bud-scales of the opening bud. Draw a single scale.

e. The wood-section.

Note on the end of the section the component parts, the bark, the wood, the cambium; the heartwood, the white wood; the lines of growth. How much has the tree increased in diameter each year? What is the average annual increase? How long at this rate would be required to furnish a pine log two feet in diameter?

LESSON XXXIX.

The Scotch Pine. — *Continued.*[1]

Materials required: Flowering branches, staminate, pistillate; cones of one year on the branches; cones of two years, and mature cones from which the seed is falling.

[1] In pleasant weather this lesson can well be studied by the pupils out-of-doors, in presence of the trees studied.

I. The Inflorescence.

a. The staminate flowers.

Examine the cluster; note that it is like a compound spike; i.e., a spike made up of spikes. Supposing each spikelet a flower, of what parts does it consist? Is there calyx or corolla? Notice the central axis and its attachment to the main stem; are there any bracts? Scale-leaves? To what, then, on the foliage branch does this central axis correspond?

Compare now a single stamen; examine with the lens. Each is a scale-shaped body flattened above, next the axis, and bears a pair of swollen sacs below. Some of the stamens have probably begun to discharge the contents of these sacs? How? How does the anther open? Draw a single stamen as it appears under your lens.

Supposing the central axis of each flower to be a branchlet, as we have seen it really is, each stamen then would be what? On which side of the leaf (dorsal or ventral) are the pollen-sacs developed? Note the abundant pollen. When convenient, examine the pollen, using a microscope of moderate magnifying power. Find two inflated empty sacs (wings), one on each side of the pollen-grain proper.

b. Note the terminal bud on the stamen-bearing branch. It is probably developing, and will later bear a few branchlets with leaves. Meantime, the staminate flowers all fall, leaving a vacant ring, or collar, around the twig. Look at last year's twigs, and find the location of last year's staminate flowers. Here we have ad-

ditional evidence that our interpretation of the flower, its morphology, is correct.

c. The pistillate flowers, the cones.

1. Find at the tips of some of the branches tiny purple cones of the season; note their posture on the tree; erect or pendent? Note place of the young cone with reference to other buds on the twig; does it come as a development of the terminal bud?

   Study now the structure of the little cone. Examine with the lens; note its form; its central axis. Is it stalked or sessile? The bracts, of two sorts, the lower (outer) thin, simple *bracts;* the upper thicker, the carpellary scales (serving the office of carpels).

   Dissect off one of the scales; notice a ridge, keel, along the middle; on which face of the carpel is it? Find at the base of the scale two little swellings, the *ovules,* one on each side of the keel. Perhaps you can make out with your lens a minute opening at the lowest extremity of each ovule. Supposing the bract upon the axis as before to subtend a branchlet, then where are the leaves?

   Remember how the ordinary leaves stand facing each other. Imagine the two leaves grown fast together by their posterior (next the axis) edges, the anterior edges remaining free and becoming divergent; the line of union would form the keel of our little carpellary scale, and the ovules, although next the axis now, are

really developed on the *back* (lower outer, rounded surface) of the leaves, just as the pollen-sac is formed on the back of the leaf of which the stamen is the representative.

Draw a scale to show all that you can make out under your lens.

2. Compare now a cone one year old. Note upon the tree the posture of such a cone; erect or pendent? Note the changes that a year has brought in size, shape, color, texture. Split such a cone through the middle, and find the tapering axis; the bracts and carpellary scales in section. Note the changed shape of the latter, so that the space between their tips is completely filled up; the cone is solid.

Find the white ovules at the bases of the scales; probably not all scales have proved fertile. Dissect out a fruiting-scale, and draw to show at least the upper surface.

3. Compare a cone of two years, noting its position on the tree as before compared with the cone of one year. What changes can you observe? Compare a cone that has reached full maturity on the tree, the scales all reflexed. Find the black seeds, the fully developed ovules. Note the broad transparent wing with which each seed is furnished. Compare the samara of the Maple. Draw a mature seed. Explain with reference to the development and dispersal of its fruit; the several positions and phases of the cone.

II. The Fertilization.

By what agency is pine pollen transported? What adaptation in the pollen-grain? Such pollen from Pine forests is sometimes carried hundreds of miles. In the young cone what adaptation for the reception of the flying pollen? Notice that in the pistillate flower there is no style; the pollen-grain rolls down the tiny scale, and lodges directly against the micropyle. Fertilization is then effected practically as in the Trillium, though much more slowly.

The surprising thing about the cone is that its ovules for fertilization lie thus open to the world. For this reason the great Scotch botanist Robert Brown called such plants as the Pines, and the cone-bearers generally, *Gymnosperms* (Gk. *gymnos*, naked, and *sperma*, a seed). Plants like the Trillium, for instance, in which the seeds are developed in a closed ovary, are called, by way of distinction, *Angiosperms* (Gk. *angeion*, a vessel).

LESSON XL.

The White Pine.

PINUS STROBUS LINN.

Materials required: Mature cones of the common Pine; twigs bearing the fresh foliage. The pupils should have access to trees which may be freely examined.

The Scotch Pine, as its common name would indicate, is not native to North America. By Englishmen

the tree is called the Scotch Pine; but it is, in fact, the common Pine of all Northern Europe. Linné, when he first proposed for the tree its scientific name, called it therefore simply *Pinus sylvestris*, the Pine of the forest.

America, however, is especially the land of Pine-trees. One of the most widespread species is that known as White Pine. It ranges as far west as Iowa, makes up what remains of the once splendid forests of Wisconsin and Minnesota, and is commonly planted throughout the whole country.

1. Let the student now carefully compare the White Pine[1] with the Scotch Pine in the various particulars enumerated in LESSON XXXIX., and bring in a written report of his observations.

2. Let the student especially compare the cones of the two Pines: —

a. In structure; relative size; size and shape of the carpellary scales, pointing out the particulars in which the cones of the two trees agree and differ.

b In the history of their development. How many phases of the cone of the White Pine are found at one time upon the tree?[2]

3. Let the student discuss the economic value of both trees. For what purposes are both planted? What is the source of the Pine lumber in common use?

[1] If the White Pine be not accessible, some other may be selected, as circumstances may dictate.

[2] The White Pine is in bloom a little later with us than *P. sylvestris*.

LESSON XLI.

More Relatives of the Scotch Pine.

Materials required: Cones and coniferous fruit of every description; the greater the variety the better. The following will probably be included; cones of:—

Pinus strobus L.,	The White Pine.
Pinus sylvestris L.,	The Scotch Pine.
Pinus austriaca Hoss,	Austrian Pine.
Picea excelsa Link,	Norway Spruce.
Thuja occidentalis L.,	Arbor-vitæ.
Juniperus virginiana L.,	Red Cedar.

I. MORPHOLOGY.

1. First compare the cones of the Austrian with those of the Scotch Pine and those of the White Pine. Although all different, yet in some particulars they all agree. As in our comparison of the Maples, these particulars enter into a definition of the genus (kind) *Pinus*.

2. Compare next the cones of the Spruce with those of the Scotch Pine. Should the Spruce be put with the Pines? Why not? Draw a single scale of the Spruce cone, and compare with the drawing made of the scales of the Scotch Pine cone. Compare the scales; the seeds.

3. Compare the cones of the Arbor-vitæ with those of *P. sylvestris*. Note the difference in the arrangement

of the scales; but consult the arrangement of the foliage leaves in the two forms compared.

4. Compare the cones (berries) of the Red Cedar. These seem to be farthest away of all. These are cones true enough; you may count the component coalescent scales. We have here simply a specialization of cone structure, adapting it to a new mode of fruit dispersal. How is the fruit (seeds) of the Pine scattered? What can be the meaning of this soft semi-edible fruit? What is the significance of edible fruit in general?

II. CLASSIFICATION.

All these plants are like the Scotch Pine, not only that they are gymnospermous, but they are, as we see, all cone-bearers as well; that is, they all belong to a large group of the plants known as the

ORDER CONIFERÆ.

in which the typical fruit is a cone like that of the Pine; but it may be greatly reduced in the number of fruiting-scales, even more so than in the Cedar. In our species of Yew, for instance, obtainable in some localities, the fruit is a one-seeded little red berry, representing, apparently, a single scale.

The order *Coniferæ*, then, includes all the Pines, all the Spruces, Larches, Firs, Cypresses, Cedars, Yews, of the world. It is thus a magnificent order, and includes many of the finest specimens of plant-life now on the earth. For example, the Sugar Pines of California (*P. lambertiana*) are much like our White Pine, but reach a height of two hundred and fifty feet, and a

diameter of fifteen feet! The giant Redwoods (*Sequoia gigantea* and *S. sempervirens*) of the Sierras and Coast Range in California are larger still! Such trees are, of course, of great age. The largest have stood on earth from fifteen to twenty centuries, and well merit preservation at the hands of enlightened governments, to say nothing of enlightened private owners.

III. Economic Value.

From what has been said and learned, it will appear that the economic value of the order is simply incalculable. Nearly all the trees mentioned in the last paragraph are lumber-trees. Let the pupil endeavor to find out the species of tree from which comes each of the following products of the mill: —

Soft Pine lumber.
Hard Pine lumber.
Cypress lumber.
Redwood shingles.
Cedar shingles.
Hemlock lumber.
Spruce lumber.

LESSON XLII.

The Common Locust.

ROBINIA PSEUDACACIA LINN.

Materials required: Branches in full bloom; dry fruit of previous years; wood-sections as usual; pods of the Honey Locust and other leguminous plants, as

the Peanut, the Pea, the Bean; young shoots a year or two old; peas and beans softened by soaking in water.

I. GENERAL DESCRIPTION.

Let the pupil, as in case of trees previously studied, give account as full as possible of what may be discovered by studying the species in the field.

a. Its habitat, habit of growth, resultant outline, form; reproduction through sprouts from roots, running sometimes for great distances in loose soil.

b. The bark; on younger shoots and branches thin and striped, later on larger stems black and rugose. The thorns, their persistence. The wood (as seen in sections); white wood, *alburnum;* heartwood, *duramen.* Qualities of the wood; its hardness, density, strength, susceptibility to polish, economic value, uses, imperfection.

II. THE FOLIAGE.

a. The compound leaf borne on the conspicuous new branchlets. Note the persistent bud-scales, velvet-lined; enumerate the parts of the leaves; in young leaves note the manner of unfolding; the leaflet, its form, venation. Notice the swollen base of the petiole; the *pulvinus.*[1] The stipules which produce the thorns are tardy of appearance. See LESSON II., II., *h,* and XV., v., *b* 2.

b. Note the position assumed by the leaves at nightfall; compare with the diurnal position. Is the Locust a "sensitive plant"? Many plants change the position of their organs as external conditions change. Compare the Oxalis at home, or the Clovers in the dooryard.

[1] See Vine's "Physiology of Plants," p. 532 *et seq.*

The Barberry-bush is notorious for the movements of its stamens.

All these plants are sensitive, we say; but by appropriate means we may demonstrate the sensitiveness of many others. All plants are sensitive, but most are slow to respond. Such plants as the Barberry, the Locust, the *Mimosa* (Sensitive-plant proper), are exceptional. Perhaps the slow peculiar collapse of the Locust leaves at evening is due to diminished light and warmth; but the Locust, as well as many other plants, seems to have formed the habit of *sleeping* at night. The activities of the plant are suspended at regular intervals. The pulvinus is doubtless in the Locust the organ by which change of position on the part of the whole leaf is effected.[1]

III. The Inflorescence.

a. Its general form, more or less perfect racemes borne on the wood of the season. Note the odor, color, and abundance of the flowers; the posture of the individual flower on the drooping raceme.

b. The single flower; zygomorphic or actinomorphic? Find a pair of bractlets (early caducous) at the base of the pedicel.

1. The downy, spotted monosepalous calyx, its teeth alternating with the petals within.
2. The petals; their peculiar forms and adaptation to each other, lending to the flower its expression so to speak. The older botanists saw in such a flower resemblance to a butterfly (Lat. *pa*

[1] See Darwin, "The Power of Movement in Plants," p. 311.

pilio), and named such flowers papilionaceous. The several parts of a papilionaceous flower have likewise received special names. Thus, the broad upper petal is the *vexillum*, or *standard;* the lateral petals are called *wings;* while the remaining two anterior, somewhat cohering, taken together constitute the *keel.* Are these names appropriately applied? Note in the unopened flower the position of the petals; which petal is outermost?

3. But the peculiarities of the papilionaceous flower do not stop with the petals. With a sharp razor cut the flower vertically through the middle, so as to split the keel, and expose a vertical section of the whole flower. Observe the position of stamens and pistil with reference to the enclosing petals.

4. Notice the cohering filaments of the stamens; how many of these are thus consolidated? Where stamens are all united by their filaments they are said to be *monadelphous;* if united to form two sets they are *diadelphous.* Which term is applicable here?

   Strip off the petals, and notice the opening on the posterior side at the base of the stamen-tube.

5. The pistil; notice its form, pedicel in the centre of a nectar-bearing disk; the ovary, style, stigma. With the lens find below the stigma a collar of projecting bristles, probably covered

with pollen. Compare with the young pistil the dry fruit, its two valves, single row of seeds. Compare pea-pods, bean-pods, if obtainable. Notice the dehiscence by separation of the valves along both sides. Such a fruit as that of the Locust or the Bean is called a *legume*.

6. Sketch a vertical section of the flower, to show the details observed. Sketch the summit of the style, to show the surrounding bristles.
7. Examine the seeds; the cotyledons. Compare peas or beans that have been softened a little while in water. Note that the cotyledons fill up the entire seed, no "albumen;" i.e., the seeds are *exalbuminous*.

LESSON XLIII.

The Common Locust. — *Continued.*

ROBINIA PSEUDACACIA LINN.

Materials required: Locust branches in full bloom, as in the preceding lesson.

I. FERTILIZATION.

a. Study once more the form of the fully opened flower; color, odor, nectar, plainly proclaim the flower adapted to insect visitation. Let us note particularly these general features: —

1. The display of color emphasized here by the shape and place of the banner; note the spot in the middle.

2. The odor, especially on sunny days, rich and far-reaching, summoning, we may believe, from far all winged creatures that have noses refined and keen.

3. The nectar waiting inside the stamen-tube, at its base, for the tongues of such creatures as can find and reach it.

b. Hold now the flower in one hand, and with the thumb and finger of the other push down gently the wings, and see what happens. What would occur should a bee impose his weight as you have applied the pressure of your fingers? The flower in respect to fertilization possesses a certain mechanism; each part has its appropriate office. The banner, by its size and position, assumes the function of display; the wings afford a landing-place; the keel encloses pistil and stamens in most delicate adjustment. Even the style shows special modification; witness the bristly collar.[1] What purpose do the bristles serve?

c. Is self-fertilization possible in these flowers? Is wind-fertilization possible?

II. DISTRIBUTION.

The Common Locust has a wide distribution in the Eastern United States, ranging from Pennsylvania to Iowa, and southward. It is strictly an American tree,

[1] Read Gray's "Structural Botany," p. 225 *et seq.*

although now planted commonly in the parks of the Old World, and said to spring in some places spontaneously, as if naturalized.

III. CLASSIFICATION.

Relatives of the Locust have already been named. A very large series of plants, including the Lupines, Brooms, Clovers, Wistarias, Peas, and Beans not only all have papilionaceous flowers and leguminous fruits, but, besides, have just that arrangement of petals which we have seen in *Robinia;* i.e., the standard in the bud is outermost. These make up the Pulse family proper, the *Papilionaceæ*. Then, we have another somewhat smaller group of plants, all of which have leguminous fruit; but while some have papilionaceous flowers, others have flowers which are almost, if not altogether, actinomorphic. But even those in this case which have papilionaceous flowers do not show the same *estivation;* that is, the petals in the bud are differently arranged, the vexillum being included, tucked under the wings. Examples are seen in the beautiful Red-bud, *Cercis canadensis*, fortunately familiar in some parts of the country, and showing its flowers all over the otherwise naked branches, before the leaves; the Honey-locust, *Gleditschia triacanthos*, with beautifully pinnate leaves and small greenish flowers; the Coffee-tree, *Gymnocladus canadensis*, a fine ornamental and forest tree with regular flowers, and having about the same range as our Locust, but far less known than it deserves to be. These three trees are types of the family *Cæsalpineæ*.

Finally, there is a large series of plants, though

poorly represented in the Eastern part of our country, which have as their type the real "Sensitive-plant," *Mimosa pudica.* Such plants are not papilionaceous at all, but they have leguminous fruits and characteristic compound foliage. This third set of plants make up the family *Mimoseæ.* All the families agree more or less perfectly in fruit. Everywhere the type is a legume. Hence the three families, with their hundreds of species, are classed together in one of the most important natural orders of the plant world, the

ORDER LEGUMINOSÆ.

Let us recapitulate the characters of the order: —

1. Leaves { compound, alternate, stipulate.
2. Ovary { simple; in fruit a legume.
3. Seeds, — exalbuminous.

LESSON XLIV.

Rye. — STEM AND LEAF.

SECALE CEREALE LINN.

Materials required: A few entire plants of Rye from the field, the roots carefully washed to show the root system, the origin of the several stalks, etc.; numerous single stalks, some ready to bloom, some in full flower,

some in later stages of development, if obtainable; a dry cornstalk.

I. General Description. Note: —

a. The several parts of the plant, — root, stem, leaves, inflorescence. Distinguish from the roots the subterranean part of the stem, observing the peculiar branching by which each plant appears as a collection of stems consolidated at the base. Perhaps the original grain of rye may still be found from which the entire cluster rises. This peculiar branching of grasses at or in the ground is called tellering, or stooling.

b. The roots; their origin in successive sets, each set a little higher up than the preceding, so that the youngest are near the surface of the ground, or even above it! Look at the cornstalk, and recall its "bracing roots" (Lesson X.).

Note the structure of the root, a tough, fibrous, central cylinder, the fibro-vascular part, and the softer, thicker cortex, the latter thickly covered with *root-hairs.* These can best be seen by laying the root in water over some dark surface. They make the surface of the root like velvet. They are, as before noted, the absorbent organs of the plant, penetrating between smallest particles of earth, and are responsible for much of the difficulty experienced in washing the roots clean. The root-hairs can even be seen in the dry ground when the plant is first pulled up, extending like hundreds of fine cobweb threads into the adhering earth. The importance of these organs cannot be over-estimated; if they become dry the plant dies. Why do transplanted trees so often fail to grow?

c. The stem. Notice the short white subterranean part, the straight ascending stalks, each simple, erect, terete (round), smooth, hollow, jointed. Such a stem is called a *culm.* Is it hollow throughout? Smooth?

1. Observe the distinct nodes, long internodes, shorter below. Make a vertical section through a node, so as to include part of the internode above and below, and draw, enlarged about three times, so as to show the structure. In younger stems find traces of pith. Compare the cornstalk.

2. With the lens notice the stripes on the surface of the culm. Cut a smooth section just above one of the lower nodes, and on the section find the ends of the fibro-vascular bundles. The bundles are closed, though here arranged in a ring (LESSON VII.). We may consider the case like that of the cornstalk with the central bundles undeveloped. Is there any relation as regards position between the bundles and the surface stripes? Sketch a cross-section enlarged, and mark the place of the bundles.

d. The foliage.

Note the leaves; their form, arrangement, attachment. Observe that the petiole takes the form of a sheath, and contributes so far to make strong the stem against the onset of the wind. (Compare LESSON V.) The split in the sheath; does it extend all the way down? At the point where the blade meets the stem, find the *ligule*, a thin, papery structure, the upward ex-

tension of the sheath; observe its shape, margin; probably takes the place of stipules.

Study the blade of the leaf; its edges, surface, venation. The veins are white; the green stripes are the chlorophyl-bearing part, the *mesophyl*. Note the form assumed by the leaf in drying.

LESSON XLV.

Rye. — *Continued.* — FLOWER AND FRUIT.

SECALE CEREALE LINN.

Materials required: The same parts of the plant as before; boxes of various grains, Rye, Wheat, Oats, Corn, etc.; a few grains of each sort softened by soaking a short time in water.

I. THE INFLORESCENCE.

Examine the fresh spikes of Rye, and note: —

a. The general form of the entire inflorescence, flattened-spicate; the axis, here called the *rhachis*, the culm continued through the spike. Strip the rhachis for a short distance below, and note its shape, "zigzag, jointed."

b. The primary divisions. Bend the spike against its longer diameter; the whole inflorescence separates into similar divisions, the *spikelets*. Isolate a single spikelet, and observe its position; sessile at one of the joints of the rhachis, alternate with others above, below. Compare the leaf arrangement.

At the base of each spikelet find a pair of small, slender bractlets, one on each side, to right and left, the *glumes.* The spikelet is the unit of inflorescence of the Rye; the *unit of inflorescence* in all *grasses,* of which the Rye is here taken as type. Whatever the general form of the inflorescence, the glumes (generally two, sometimes only one) limit for us the spikelet, and determine its identity. Examine one of the glumes carefully; note its parallel veins, their number; draw enlarged.

c. The flowers.

1. Between the glumes[1] find three flowers; two large, conspicuous, the third a minute rudiment between the other two, and likely to be overlooked. Each flower consisting of stamens and pistil is enclosed again by bracts, two of them; the outer, larger one here is called the "flowering glume;" the inner, the palet.[2]

   Study the flowering glume; note its sharply serrulate, somewhat infolded margin. Is the margin alike on both sides? Note the veins, their number; the apex, continued into a long, rough awn. Draw.

   Compare in all particulars the palet. Note especially its delicacy, its infolded margin. Draw.

[1] Sometimes designated "*empty glumes,*" because there is nothing in their axils.

[2] Sometimes called "outer" and "inner" palets; i.e., glumes enclose the spikelet, palets the flower: this is the usage of systematic works.

2. Study the stamens. Observe their number; the thread-like filament; the large anther, its lobes and dry, powdery pollen. Compare the stamen in bud and bloom. In what does "blooming" consist? Sketch a stamen enlarged.

3. Study the pistil; note its parts, — the sessile, silky ovary, the branching style, and plumose stigmas, exquisitely delicate. Draw as they appear under the lens.

4. At the base of the ovary notice the small white papery scales, *lodicules*, organs which perhaps stand for petals or sepals in this simple flower.

II. THE FRUIT.

a. The dry grains. Compare Oats, Corn, Wheat, and Rye. In what does the Oat differ from the rest? Strip off the chaff (flowering glume and palet), and then compare. In the Rye-grain find the longitudinal groove, and a scar or depression on the opposite side, at the base. Find the same features in the other grains.

b. Take grains that have lain for some time in water; from the Rye-grain strip off the covering, the consolidated wall of the ovary and seed-coats, and at the place marked by the "scar" expose the new plantlet, the embryo. It is small, but can be well seen, plumule upward, radicle downward, toward the base of the grain. The parts are larger in a grain of Corn, and we may accordingly transfer our investigations to that grain.

c. From the grain of Corn strip off the covering as before; the embryo lies plain and white against the sur-

rounding mass of the grain, the so-called *albumen.*[1] Draw the face of the grain enlarged about twice.

Lift out the embryo, and from the upper end, proceeding downwards, make a series of sections, and so ascertain the place and form of the single cotyledon. The embryo proper lies ensheathed in the largest, outermost leaf, the cotyledon.[2] This, in turn, lies against the albumen, is an absorptive organ, and never becomes functional as a green leaf.

d. With the point of a penknife or scalpel dissect away the cotyledon, and disclose the remaining parts of the embryo.

e. With a sharp razor make a vertical section through the embryo as it lies in the grain, and find: —

1. The *plumule,* made up of several leaflets, one wrapped within the other.

2. The *radicle,* extending downwards, and forming the end of the embryo opposite the plumule. Clothing the tip of the radicle, the *root-sheath* can be plainly seen. This is broken through on germination. Underneath this, and capping the tip only of the radicle, is the *root-cap.* When the radicle grows, the root-cap protects its advancing tip as it pushes through the ground. The root grows at the tip, and the root-cap is renewed from the inside, while its outer layers wear away.

[1] See Gray's "Structural Botany," pp. 25, 26.

[2] Called also the *scutellum.*

3. The *caulicle.* This is the embryo-stem, and includes the short structure lying between plumule and radicle. In favorable sections, from the caulicle secondary roots can be seen emerging as small, rounded swellings.

f. Draw a vertical section of the entire grain of Corn, to show all the structures observed.

LESSON XLVI.

The Ground Ivy and the Mints.

Materials required: Fresh specimens of Ground Ivy (*Nepeta glechoma* Benth.) in flower and fruit. Similar specimens of American Pennyroyal (*Hedeoma*), Skullcap (*Scutellaria*), Motherwort (*Leonurus*), and any other Mint obtainable.

A. The Ground Ivy.

Study the Ground Ivy. Examine: —

I. The Plant.

What is its duration? Note its general appearance and habit of growth. Also the odor of the herbage.

Examine the parts in detail: —

a. The root. Note the kind, form, color, etc., of the roots. Notice the development of roots along the stem. From what points do they arise?

b. The stem. Note the texture, direction of growth, length, structure, color, surface, and particularly the form of cross-section of the stem.

c. The leaves. Determine the kind of leaf. Note also the venation, form (general outline, base, and apex), margin, surface, texture, and the parts of the leaf.

Examine the lower surface of the leaf with a lens, and observe the scattered dots or glands. These secrete the volatile oil which gives the plant its characteristic odor.

Are these glands found on the upper surface? On the petioles and stem?

II. THE INFLORESCENCE.

a. Study the arrangement of the flowers. What is the order of inflorescence? Do the flowers form clusters? Note the length of the pedicels.

b. The individual flower.

Is the flower complete? Regular? Symmetrical? Examine the parts: —

1. *The calyx.* Note its form, color, and surface. Also the number of vertical ribs or *nerves.* Observe the number, form, surface, etc., of the lobes. Are they equal?

2. *The corolla.* Note the form, length (as compared with calyx), color, and surface of the corolla. Also the number, form, and size of the lobes, and their arrangement. Compare the length of the tube and lobes.

3. *The andrœcium.* Observe the number and insertion of the stamens, and their length as compared with the corolla.

Are the stamens equal in length, and equally inserted? Notice that they are in pairs. Compare these pairs as to length and position.

Describe a single stamen, noting the length, surface, and color of the filament; the size, color, number of cells, and dehiscence of the anthers; the color and abundance of the pollen.

4. *The gynœcium.*

I. Is the pistil simple or compound? Note the division, number of cells, and number of ovules in each cell of the ovary. Also its position with reference to the calyx. Observe the size, form, number, surface, color, etc., of the divisions of the pistil.

II. Study the fruit. How many distinct nutlets are produced by each flower? Note the form, size, color, and surface of the nutlets.

5. *The torus.* Note the presence of a fleshy disk. Observe its color, size, form, etc.

III. Describe the whole plant, and make drawings of characteristic parts.

IV. POLLINATION.

a. Examine a fresh flower again. How is fertilization accomplished? Study in detail the adaptation of form, color, odor, and surface of the flower, and the relative position of the essential organs to cross-fertilization. Note particularly the distribution and arrangement of colors, and the *zygomorphism* of the flower.

Examine the base of the tube of the corolla. What is the significance of the swollen portion?

b. Observe the plant in the field. Do insects visit it? If so, what kinds, and how do they enter?

c. Make a drawing of the longitudinal section of the flower, showing the position of the several parts, and one of a front or face view of the flower.

Discuss all the adaptations to pollination in detail.

V. HABITAT AND DISTRIBUTION.

a. Note the kind of locality, or habitat, which this species affects. Record also the date of flowering and fruiting.

b. The species was introduced into this country from Europe. It is now generally distributed throughout the Eastern United States, extending westward to Nebraska.

B. RELATED SPECIES.

I. Make a comparison of the species listed at the head of this lesson, or others, noting particularly the following characters: —

a. The plant: its aromatic odor.

b. The stem: its texture, and form of cross-section.

c. The leaves: their position on the stem; the surface, and parts.

d. The calyx: its form and position, division, and duration.

e. The corolla: its form, division, and number and arrangement of lobes.

f. The stamens: their number, position, and arrangement.

g. The pistil: number of cells and division of the ovary, and number of ovules in each cell; kind of fruit; number and division of styles.

II. CLASSIFICATION.

Observe that all the forms studied agree in the following characters: —

They are mostly aromatic herbs with four-angled stems; opposite, glandular, ex-stipulate leaves; monosepalous, tubular, inferior, persistent calyx; monopetalous, labiate corolla, its upper lip two-lobed or entire, its lower lip three-lobed; didynamous or diandrous epipetalous stamens; a deeply four-lobed ovary, which in fruit forms four distinct one-seeded nutlets; and a single style, two-lobed at apex.

Plants possessing these characters form the

ORDER LABIATÆ.

The Mint Order.

The plants of this order will be found to differ from each other principally in the number and relative length of the stamens; in the lobes of the corolla; and in the number of lobes, length, form, and number of nerves of the calyx.

Upon these characters especially is based the subdivision of the order into tribes and genera. The Ground Ivy belongs to the genus *Nepeta*, and its name is *Nepeta glechoma* Bentham. Of the remaining species listed, the Skullcaps belong to the genus *Scutellaria;* the American Pennyroyal to the genus *Hedeoma;* and the Motherwort to the genus *Leonurus.*

III. Distribution and Economic Value.

The Mint Family contains about two thousand five hundred species, distributed principally in temperate and warm regions. About two hundred species are natives of North America.

A number of species yield valuable essential oils. The best known are: Peppermint (*Mentha piperita* L.), Lavender (*Lavandula vera*), and Pennyroyal (*Hedeoma pulegioides* Pers.).

Many other species are used as domestic remedies, the most common being the following: Hyssop (*Hyssopus officinalis* L.), Balm (*Melissa officinalis* L.), Catnip (*Nepeta cataria* L.), and others.

The American Pennyroyal (*Hedeoma pulegioides* Pers.) and White Hoarhound (*Marrubium vulgare* L.) are still recognized as officinal.

Among common garden forms may be mentioned Rosemary (*Rosmarinus officinalis*), Thyme (*Thymus vulgaris*), Garden Sage (*Salvia officinalis*), Sweet Marjoram (*Origanum marjorana*), and Sweet Basil (*Ocimum basilicum* L.).

Several tropical species belonging to the genera *Salvia*, *Coleus*, and *Perilla* are cultivated for ornament.

LESSON XLVII.

The Blue Grass.

POA PRATENSIS LINN.

Materials required: Plants of Blue Grass in full bloom. If convenient, let the class study the plant in the open field. The flowers are best expanded and in best condition for study on sunny mornings. The parts of the flower are very small, but in favorable light can be easily seen under the Coddington.

I. Study all the characteristics of stems, leaves, roots, as in the case of Rye, and record what you observe. Notice that the stooling is much more prolific in the Blue Grass, and that the branches push often for considerable distances below the surface of the ground, and so form a *sod*. Very few grasses form such a complete covering for the soil. Most grasses, especially in the warmer parts of the world, grow in isolated tufts, like the Rye.

II. THE INFLORESCENCE.

a. Note the graceful form, an open panicle made up of alternate clusters of branches. Observe the number of branches at a node, and make a simple sketch to show their arrangement.

b. The spikelet, sessile on the ultimate divisions of the branches, each with its well-developed but unequal glumes. How many flowers in a spikelet? the upper, central, usually undeveloped.

c. With a needle push back the empty glume, and study the flowering glume from without. In sunny weather, nearly all details can be made out without dissection, the flowers being widely open. Notice the blue color and its display.

Break up the spikelet, and notice the mass of cobweb-like hairs at the base of the flowering glumes.

d. Draw a spikelet enlarged, to show as many details as possible.

III. FERTILIZATION.

How are the flowers fertilized? and what are the special provisions for the agency employed?

IV. ECONOMIC VALUE.

What is the principal value of Blue Grass in this country? Is its value great? In what other ways is it valuable?

V. DISTRIBUTION.

A native of northern Europe, it is now found in all the cooler parts of the United States and Canada. At first imported and sown for pasturage, it is now everywhere indigenous, rapidly displacing the original vegetation, occupying meadows, woodlands, prairies, roadsides, especially where the soil has been disturbed by cultivation.

In a similar way study any of the following as they come to bloom: —

Orchard Grass,	*Dactylis glomerata* L.
Wild Barley,	*Hordeum jubatum* L.
Oats,	*Avena sativa* L.

Timothy Grass, *Phleum pratense* L.
Sand-bur, *Cenchrus tribuloides* L.

Later on the pupil should study for himself some species of Panic Grass — as *Panicum sanguinale* L., and especially Indian Corn, which is not only a beautiful grass, but is wonderfully interesting, and worthy of study in every way.

All grasses are members of a single natural order, the

GRAMINEÆ.

Of this order the leading definitive characters may be gathered from any of the types we have studied. Thus: —

Stems { in structure, endogenous;
in form, culms.

Leaves { in form, linear,
with petioles sheathing;
ligule-bearing.

Ovary { simple; styles two;
in fruit, a grain, caryopsis.

Of the importance of the order too much cannot be said. Here belong the principal food-producing plants of the world. Thus: —

Secale cereale L., Rye.
Triticum vulgare L., Wheat.
Avena sativa L., Oats.
Zea mays L., Corn.
Oryza sativa L., Rice.
Hordeum vulgare L., Barley.
Saccharum officinarum L., Sugar-cane.

Sorghum vulgare gives us in one variety the Sorghum or Sugar-cane of the Northern States, and in another, Broom-corn.

Timothy, Orchard Grass, and Blue Grass furnish food for our cattle. On the other hand, some of the grasses are very troublesome weeds. Thus: —

Setaria glauca Beauv.
Setaria viridis Beauv.

are common Foxtails; some of the Panic Grasses, and in sandy ground the Sand-burs, are no less troublesome.

But for a thorough investigation of grasses, as well as of other flowering plants, and their identification, a Manual is necessary. Several works of this kind are at hand, and to these for his increase in knowledge the student is henceforth referred.

LESSON XLVIII.

A Lesson on Ferns.

OSUMUNDA CLAYTONIANA LINN.

Materials required: 1. Let the pupils, where practicable, visit the woods in May or early June, according to the locality and the season, and find of as many Ferns as possible the budding, unrolling fronds. The species named will be most conspicuous, and probably most common. A few tufts, rootstock and all, should be taken to the classroom.

2. Herbarium specimens of *O. claytoniana* in fruit.

Fresh specimens from the woods can be had a week or two after the fronds appear.

I. THE VERNATION.

Study the rising but still rolled-up fronds of Osmunda, and note: —

a. The brown tomentum, wool, with which the young fronds are abundantly clothed. What function is suggested? (*cf.* LESSON IX. V.). If the budding fronds of other species are at hand, compare.

b. The habit of the fronds, their *vernation*, rolled or *circinate*. Unroll one of the fronds. The process can be continued but a little way because of the immaturity of the parts rolled up. By watching, however, the procedure in the field, we shall discover that the same condition of affairs is always present until the frond reaches at last complete expansion; i.e., the frond unrolls as it grows, grows in its outer, distal part long after the proximal portion is mature. This is one of the peculiarities of Ferns and their allies. Plants of this kind were formerly denominated *Acrogens*, tip-growers.[1]

II. THE FROND OR LEAF. Study first a sterile frond.

a. Compare its form with that of some pinnate leaf, as of Pedicularis. Note the several divisions. The same terms are applicable in description as in describing any leaf. However, the petiole is usually called the *stipe*, and its continuation through the leaf the *rhachis*. Note the directions assumed by the pinnæ in different regions of the frond, their unequal size.

[1] See Gray's "Structural Botany," p. 344.

b. The venation. With a lens study the venation in one of the pinnules. Note its peculiar forked character. Compare other pinnules. Is any other type of venation to be found? Draw, twice natural size, a single pinnule, to show the veining. How many veins on each side the mid-vein? Is the number constant?

III. THE FRUIT. THE FERTILE FROND. Note:—

a. The absence of flowers. This Osmunda is called the "Flowering Fern;" but the pupil will readily see that of ordinary flowers there are none.

b. The fruit. Observe that certain pinnæ are different from the others, and that these when shaken release quantities of green powdery cells. Under the microscope these are seen to be simply green chlorophyl-bearing cells, like the cells of a leaf; but the cells are all free, like the pollen-grains. These free cells are the spores of the Fern. Each cell is capable of independent growth. As it grows it produces, not the fern directly, but a tiny, simple leaf-like structure, the *prothallus*, on which appear special cells of two sorts; cells like the oösphere in the Trillium flower (See Fig. 9, B, 3.), and cells which are in function like the pollen-grains. When the oösphere is fertilized, it grows to a fern, and bears spores again. So we see that although the fern has no flowers, in our common sense of the word, it has yet, in one of its phases, a fertilization.

c. Because the spores produce the fern indirectly, that is, by the intervention of a prothallus to bear the organs of fertilization, the fern is said to exhibit an "alternation of generations," or to present two phases:

the first generation or phase proceeding directly from the spore, the prothallus, since it bears the oösphere is called the oöphytic phase; the second, resulting from the fertilized oösphere, the spore-bearing frond, is the sporophytic phase. Which phase have we in hand?

d. The spore-cases, *sporangia.*

1. Study the fruiting pinnæ; what evidence have we that they are modifications of ordinary pinnæ and their divisions?
2. Examine with a lens a single sporangium. Notice the stalk; the fissure opposite by which the spores have, perchance, nearly all escaped; a crown of small bright cells at the top of the spore-case, the annulus, here not well developed. The annulus is somewhat hygroscopic; in drying, it induces such tension as causes the sporangium to split.
3. Draw a single sporangium, enlarged sufficiently to enable you to sketch conveniently all details that can be made out.

LESSON XLIX.

Ferns. — *Continued.*

Materials required: 1. Herbarium specimens in sufficient quantity, illustrating all the more easily managed local species, as: —

Adiantum pedatum Linn.
Asplenium filix-fœmina Bernh.
Pteris aquilina Linn.
Cystopteris bulbifera Bernh.
Aspidium acrostichoides Swz.[1]

2. Fresh or dry stems of *Osmunda claytoniana* L.; fresh or alcoholic specimens of the rootstocks of *Pteris aquilina* L.[2]

I. *Asplenium filix-fœmina* Bernh.

a. Study the sterile frond of the fern, noting its form, divisions; the venation, either simple or furcate, as in *Osmunda.* Observe the veins that follow the secondary rhachis along each side. On the fertile frond —

b. The fruit. On which side of the frond is it borne; i.e., upper or lower? Differs entirely from the fruit of *Osmunda.* Distributed in minute clusters, the fruit-dots, *sori.* Each fruit-dot is called a *sorus.* Study the sorus with the lens; notice the delicate cover — the *indusium* (pl. *indusia*): peering out from the indusium edge are the brown sporangia. These are so small as to require a microscope for satisfactory study. A few may be mounted in water, and examined with a ¾ objective. Note the stalk; the annulus, here very important; the spores.

c. Note the position of the sorus, borne on the vein-

[1] In the study of these species, refer to Gray's Manual, or to Underwood's "Our Native Ferns and Their Allies," a most convenient little book.

[2] As heretofore, wherever practicable, pupils should be urged to bring in the necessary material.

let oblique to the mid-vein of the pinnule, the indusium opening outwardly. Draw a pinnule with fruit, enlarged.

II. Compare fruiting fronds of other species, as *Adiantum pedatum.* Note: —

a. The venation in the pinnules; still a modification of the furcate or dichotomous veining. Draw a pinnule enlarged to show venation.

b. The fruit; note its position at the frond margin. Examine with a lens, each sorus covered not by an indusium in this case, but by the turned edge of the pinnule, an *involucre.* If the fruit be sufficiently mature the involucre may, by assistance of a needle, be turned back, showing the sporangia attached to the involucre. Draw a pinnule to show the fruit.

III. Compare in the same fashion fruiting fronds of *Pteris aquilina,* or other species that may be at hand. Use any convenient Manual, Gray or Underwood, to determine the species of all Ferns compared.

IV. Stems of Ferns. Note: —

a. The stems of our native ferns are all subterranean; they are rootstocks, and differ greatly from each other. Compare the rootstock of *Osmunda* with that of *Pteris.* Wherein do they differ? In habit of growth? In consequent structure? Notice that Ferns are perennial; that they make progress through the earth from year to year.

b. Study the structure of the stem of *Pteris* more closely. Make a smooth section across it, and examine

with your lens. Notice the hard, brown, outer layer, the cortex; the porous strands near the centre, the fibro-vascular bundles; dissect out some of these. Notice the bands of hard, strengthening tissue that run in the same direction; the white parenchyma surrounding all. To the last-named tissue apply the iodine test. What does it show?

c. Compare the fern-stem section with the cornstalk section, the section of the Maple twig. Which does the fern-section more nearly resemble? Of the fern-section, sketch a diagram about three times natural size. Make end sections of the stipes of the various fern-fronds, and compare.

V. FERN–ALLIES.

a. Compare Ferns and flowering-plants. State all the particulars in which you find them to agree. In what particulars do they differ?

b. Closely related to the Ferns, and sometimes called Fern-allies, are the Scouring-rushes and Club-mosses. These, too, have fibro-vascular bundles like those of the flowering-plants; but, like the Ferns, they are reproduced in a roundabout way by spores. The spores in Scouring-rushes and Club-mosses are produced in spikes at the tops of aerial stems or branches, not on the backs of the leaves, as in true Ferns.

c. Compare herbarium specimens of Club-mosses and Scouring-rushes.

LESSON L.

A Lesson on Mosses.

ATRICHUM UNDULATUM BEAUV.

Materials required: A basketful of the moss fresh from the field. If not in fruit, herbarium material must be on hand sufficient to illustrate the spore-production.[1] During examination of specimens every precaution should be taken to keep the material fresh.

I. THE PLANT.

Note the cespitose tufted habit; isolate a single plant, and observe: —

a. The leafy, erect, unbranching *stem*, probably supporting at the summit the long-stalked fruit. Are the plants connected below?

b. The *leaves*, abundant, decurrent, differing in form and color on different parts of the stem. Under the lens the lowest leaves are found short, scale-like; those at the base of the fruit-stalk long and slender. Notice the arrangement on the stem.

c. Roots? Root-hairs or rhizoids? Wash the lower end of the stem in clear water, and examine with the lens. True roots are lacking; but rhizoids are abundant, forming a brown felt around the lower part of the stem.

[1] This species is common everywhere, on shady clay-banks with a north exposure, in the woods, in damp ravines. It can always be found fruiting in the fall, sometimes as early as June.

II. The Leaf.

Examine a perfectly fresh plant, using the Coddington in good light, and note all discoverable particulars concerning the leaf: —

a. The general form, color, attachment to the stem.

b. The margin, *denticulate*, furnished with minute teeth, especially towards the tip; find rows of similar teeth *across* the back of the leaf. Observe, also, that the margin is wavy. Do the undulations of the leaf and the lines of dorsal teeth correspond?

c. The apex; terminates in one or more sharp points.

d. The "mid-rib." Under the lens it may be seen that the apparent mid-rib is due to the presence, on the upper surface of the leaf, of several narrow, ribbon-like vertical green plates, *lamellæ*. Such lamellæ are rare, though on some moss-leaves even more abundant than here. Draw a diagram illustrating the relation of these lamellæ to the leaf. The lamellæ serve at once the place of a mid-rib, to stiffen the little leaves, and to increase their area.

III. The Fruit.

Select fruit-bearing stems, and note the long-stalked capsules which they carry. How many capsules on one stem?

a. If fruiting plants be heated for a minute or two in a solution of potash, and then washed in water, the fruit-stalk, the *seta*, may be easily pulled out of the tip of the leafy stem, and will show a sharp-pointed base where it was attached.

b. Notice now the little pod, or capsule, carried by the stalk; its form, symmetry, color, surface. At its summit perching —

c. The *calyptra;* a delicate-pointed hood, split down one side. With forceps lift off the calyptra, and find: —

d. The *operculum*, or lid of the capsule. Notice the long, curving, slightly eccentric beak, the *rostrum.* Draw the operculum enlarged.

e. In a mature specimen the operculum may be easily lifted from its place, opening the capsule, and exposing —

f. The *peristome*, a row of delicate teeth around the mouth of the capsule. Notice their form, color, number. The teeth of the peristome in Mosses is always some multiple of four, as 4, 8, 16, 32, etc. If the teeth stand up clearly, draw three or four together, to show their form.

g. Holding the capsule between thumb and finger, with a sharp razor split it through the middle, operculum and all, and study with a Coddington the smooth section so formed. Find the *columella*, a slender axis passing up the centre; the dark-green powdery spores in mass around the columella, between it and the wall of the capsule. These spores reproduce the Moss; hence it is we call the capsule fruit. Draw the section as it appears under the lens.

IV. Reproduction of Mosses.

a. The spore of the Moss on germination produces first a long green filament, which branches freely, and ultimately gives rise to tiny buds, which slowly unfold,

and take the form of the leafy plant. On these leafy stems, at their summits in the Moss before us, on the sides in many species, appear organs of fertilization. The examination of these transcends our present purpose; but they consist of structures bearing, respectively, oöspheres and fertilizing-cells as before. The fertilized oösphere gives rise to the stalked capsule we have seen; and as it grows, its seta becomes attached to the top (or side) of the leafy stem (inserted), whence, as we have seen, it may easily be pulled out.[1]

b. The Moss thus, like the Fern, exhibits in its life-history two distinct phases. It returns twice to the condition of a single cell. The *spore* starts the leafy phase, and the *oösphere* starts the capsule, which bears the spore again. As in the Fern, these phases are denominated oöphytic and sporophytic, respectively, according to the nature of the spore-cell which each produces.

c. Draw a sketch of a Moss-plant entire in fruit; by means of a horizontal line across the drawing indicate the point where ends the oöphytic and begins the sporophytic phase.

[1] For more complete description, consult the larger text-books, Bessey's "Botany," Goebel's "Outlines of Classification," etc.

LESSON LI.

Some Relatives of the Mosses.

THE LIVERWORTS.[1]

Materials required: Fresh or alcoholic materials of any of the larger Liverworts, especially species of *Marchantia, Conocephalus, Lunularia.* Fresh materials are always to be preferred, but alcoholic will do.

I. General Description.

Examine specimens of *Marchantia*, and note: —

a. The flattened, leaf-like *stem;* its apparent mid-rib, dichotomous branching. If the material is fresh observe the color, above, below. On the lower, ventral, surface find the rhizoids by which the thalloid stem is attached to the substratum; these float out beautifully in water. On the upper, dorsal, surface find a number of intersecting grooves, marking off the *areolation;* in *Conocephalus* the areolation is manifest to the naked eye. In the centre of each areole, find a minute opening, the stoma.

[1] The Liverworts called for here are flat, ribbon-like, green little plants found commonly creeping over moist, cool rocks or soil in shady places. *Conocephalus conicus* is the largest species, and is common in wooded districts. It bears fruit in March or April. *Marchantia polymorpha* is found in similar places, but is common in greenhouses also, and may be found fruiting from June to August. *Lunularia cruciata* occurs in this country in greenhouses only, where it may be recognized by its pale-green color and crescent-shaped cupules. For description of species, see Gray's Manual; for more thorough study *cf.* "Plant Dissection," Arthur Barnes and Coulter, p. 58.

These stomata are unusually large and well formed. They can easily be seen on *Marchantia*, but on *Conocephalus* better, are even visible to the unaided eye. What, then, is the function of this flat stem of the Liverwort? Where do we find stomata in higher plants? (See LESSON XI. IV.)

b. Examine with the lens the lower surface of the stem. Find along the middle, like slender brown lamellæ, the *leaves* divergent toward the anterior end of the stem. Their presence lends the frond its only "mid-rib."

c. Draw the stem in outline, as seen from above. Draw a small part enlarged, as it appears under the lens, to show the areolation and stomata.

II. THE REPRODUCTION OF LIVERWORTS.

A. By Buds or Gemmæ.

a. On specimens of *Lunularia* and *Marchantia* find on the dorsal surface of the stems conspicuous shallow cups, in which lie loosely small green bodies visible to the naked eye. The cups are called cupules; their contents, *gemmæ*. In *Lunularia* the cup is developed on one side only, is crescentiform. (*Cf.* the name *Lunularia.*) In *Marchantia* the cupules are beautifully symmetrical, with ornamental border. Examine with a lens, and draw.

b. The *gemmæ* are simply buds. A drop of water suffices to float them from the cupules. Once they find lodgement on suitable soil, each one is capable of development to form again a creeping frond or stem.

B. By Spores.

On some of the *Marchantia* material find erect branches very different from the flat, prostrate forms: —

a. The *antheridial branch*, short, bearing aloft a crenulate, discoid top. The stalk is called the *pedicel;* the disk, *receptacle*, contains minute sacs, in which are developed the fertilizing-cells. Make a vertical section through the receptacle and stalk in a plane corresponding to the direction of the supporting flat stem. In the section, by aid of the Coddington, you may easily see the little sacs in which are formed the fertilizing-cells. The latter are demonstrated under a good compound microscope only. Draw the section.

b. The *fertile branch*, long-stalked, bearing a star-shaped or radiate top. Count the rays. Notice that two are paired, with a deeper notch between: these are the *posterior* rays; a single ray extends in front, the anterior. Under the rays find the sporangia in various stages of development. In fresh mature specimens some will surely be found discharging their contents, a fluffy, yellow mass consisting of spores and *elaters*. The elaters are delicate, thread-like organs which aid in spore dispersal. They do not occur in Mosses. For their investigation recourse must be had to a microscope. The sporangium here, as in the Moss, results from the development of a fertilized oösphere. A vertical section through the fertile head will suffice to show sporangia of all ages, surrounded by perichætial leaves. Draw the section.

c. In the Liverwort, then, the fertilizing-cells are

produced on one specialized branch of the creeping stem, the oösphere, followed by the sporangium, on another. The spore gives rise to the thalloid plant, with its branches, the oösphere to the sporangium, with its spores; so that the succession of phases is the same as before.

LESSON LII.

The Fungi.

BLACK MOULD, — *MUCOR MUCEDO* LINN.

Materials required: 1. Mouldy fruit of various kinds, Blackberries, Raspberries. California Grapes when "too old" are apt to show beautiful specimens of Black Mould. Decaying Sweet-potatoes always show it.

2. Cultures of Black Mould under bell-jars.[1]

I. GENERAL DESCRIPTION.

a. The hyphæ. Study sowings of Black Mould that have been made on moist bread, and have been standing in a warm, moist place for a day or two. The bread will probably be found covered with an abundant white fluffy growth, resembling so much wool or cotton. The fine white filaments of which the growth consists can be distinguished by the naked eye; can be much better seen under the Coddington. These delicate filaments constitute the essential elements in the make-up of every fungus; they are called *hyphæ.* A single thread

[1] See Appendix B.

is called a *hypha*. Under the lenses of a microscope these filaments are seen to be very long, straight tubes, very rarely septate; i.e., made up of cells very much longer in one direction than others. If a microscope be at hand, mount some in water, and examine them.

Note that in the specimens before us the filaments are all free; in many fungi they are variously united to form solid structures. This will appear presently.

b. The fruit. How is the mould reproduced? There are no flowers. Examine some of the older cultures. Find hyphal branches that bear minute black spheres like tiny pin-heads. Now you may trace the spheres through various tints, from white to black. These tiny heads are *sporangia;* i.e., *spore-cases*, each a transparent sac packed full of black *spores*. The spores are simply free cells, like pollen-grains, only much smaller, and having, of course, a different function. If practicable, examine the spores in water, under a lens of pretty high magnifying power. Pass a piece of paper over the black sporangia; a black stain results. The stain consists of spores.

II. The Reproduction of Black Mould.

a. Take a piece of moist bread again, and with a clean needle touch the ripe sporangia, and then apply the point of the needle to the bread. Repeat the experiment several times, so as to make sure that some of the spores have been carried over to the bread; place under a bell-jar, and keep in a warm place. In a few days may be expected a crop of mould just as before. That is, the spores have reproduced the mould. In nature

the spores are drifted about by the wind. Each spore, when it lights upon something that will nourish it, — always some *organic* matter, — grows, produces a hypha that feeds upon the nourishing basis, branches, and flourishes vigorously, and produces at length the tufted mass that we have seen. What, then, is a spore?

b. Study again under the lens the sporangia in their various phases, from simple aerial branches, through branches whose tips are clavate, on to the small transparent spheres, then to those that are larger, becoming more and more opaque until maturity is reached. The sporangium, sac, is simply the terminal cell of an aerial branch, in which the abundant spores are formed as free cells in much the same way as pollen forms in the anther sac.

III. Record all the observations made, and draw enlarged the various phases of the fruit.

IV. The Black Mould possesses, as we have said, the characteristics of a true Fungus; it is made up of simple hyphæ, and is *dependent* upon organic matter for its food-supply. In these respects the Black Mould is a typical Fungus.

Why is it that such plants are thus dependent? What do they lack which would make them independent? In this particular how do plants compare with animals? Notice that the fruit, potato, bread, is consumed by the mould. This is not so apparent by diminution in bulk as by chemical change revealed to us through our sense of taste. The fruit yields up certain compounds whose elements nourish the mould. In

canned fruit, for instance, if the process continue a long time there is left little but dirty water.

LESSON LIII.

The Fungi. — *Continued.*

THE AGARICS, TOADSTOOLS AND MUSHROOMS.

Materials required: A basket of fresh Agarics from the field. Specimens may usually be found in abundance after the rains of spring, near decaying stumps and logs, in the woods, about manure-heaps, etc. In the cities the edible mushroom may be obtained fresh from gardeners. Many fungi are hard, durable structures, persisting through the year. Of such, gathered from logs or stumps, a basketful may be brought in for comparisons.

I. THE AGARIC.

a. The spores. Supposing plants of the mushroom type to be in hand, cut off the expanded part of one, and place it right side up on a sheet of white paper, where for an hour or two it may remain undisturbed. On the paper presently will be found the spores; notice their color and arrangement or dispersal. Under the microscope these spores may be shown to be simple cells, just as in the Black Mould.

b. The structure. Note: —

The parts of an Agaric, the stipe, or stem, supporting an umbrella-shaped top, the cap, or *pileus*. The stipe

may be solid or hollow, or furnished with a pith, *stuffed;* it may be fibrous or cartilaginous. The pileus bears on the under surface the gills, or *lamellæ;* the surface of the lamellæ is called the *hymenium.* It is on the hymenium that the spores are produced; and from this, as free cells, they fall. The pileus may be at first pressed close down against the stipe, like a closed umbrella, or may have its margin inrolled against the stipe. In either case the margin is often attached to the stipe by something like a web, a portion of which may adhere to the stipe, and leave, when the pileus expands, a ring around it, — the *annulus.*

c. Description.

Write a description of the specimen in hand, describing the several parts, their form, surface color. Mention the color of the spores, and give the size of the specimen; height and width when fully expanded.

d. Make of a good specimen a median, vertical section, and draw natural size in outline, to show all details of form and color observable.

II. Special Agarics.

The Agarics flourish from May to November. Some species occur in spring only; some are very abundant only in the fall. The species are difficult of identification, and require special literature. Two species may suffice here as examples.

1. *Agaricus sublateritius* Schæffer.

Pileus yellow, the disk reddish-brown, fleshy, convex, then expanded, at first silky, then glabrous; lamellæ not broad, adnate, yellowish, olive-green, then purple or

purplish brown; stipe equal, sometimes silky or fibrillose, and brown at the base, hollow or stuffed. Height two to six inches. Pileus two to five inches. Spores purplish. Inedible.

This is one of our common species. It is more abundant in fall, but may be found growing in crowded tufts around old stumps every month in the year. It is a very suitable species for study, although the annulus is slight, and the veil reduced to a few cobwebby threads hanging to the edge of the pileus.

2. *Agaricus campestris* Linn.

Pileus white or dusky, fleshy, plano-convex, floccose-silky or scurfy, the margin surpassing the lamellæ; lamellæ free, rounded, at first pink (very delicate), then brown, at length almost black, watery; stipe stuffed, smooth and white; annulus not large, about midway on the stem. Height two to four inches; pileus the same. Spores purplish black. Edible.

This is the edible mushroom, *the* mushroom. It is found not uncommon from June to November in rich gardens, about manure-heaps, etc.; in hot-houses at all seasons of the year. It may be recognized by the color of the gills; at first, as the pileus expands, *pink;* then, as the veil breaks and disappears, *becoming brown;* at last almost *black.*

This is also a very fine species for study, but is not so common as many other species.

III. Other Common Fungi.

a. Pupils are apt to bring in many of the more persistent Fungi. Of these perhaps the most common will

be species of the genus *Polyporus*, Polypores, Bracket-fungi, a genus distinguished in that the lower (fruiting) surface is made up of pores instead of plates. In these pores the spores are developed, and from them fall. Make vertical sections, study, draw, and describe as before. Some of these plants have hard tissues, but nothing like fibro-vascular tissues.

b. Coprini. All agaricine plants are very putrescible; some are specially transient. These spring up in a night, and perish by mid-day. They have black spores, and distinguish themselves by dissolving sooner or later into an inky fluid. Such belong to the genus *Coprinus*. The larger forms are edible when fresh.

IV. Parasitic Fungi.

We have seen that it is characteristic of Fungi to live upon organic matter. Those we have been studying are no exception. Upon what do the Agarics live? the Polypores? Can you judge by the localities in which they are found? All such Fungi living upon *dead* organic matter are called *saprophytes*.

But all Fungi are not so considerate. There are many that prey upon living organisms. Such are called *parasites*. All rusts and blights belong here. Thus the "Cedar Apples" are the fruit of a fungus parasitic on the Cedar. Grain-rust makes havoc in our fields of wheat and oats, as every farmer knows; while Lilac-blight whitens the leaves of every lilac-bush in all the country.

V. In all these cases, whether the fungus be parasitic or saprophytic, it is distinguished, just as the Black

Mould, by simplicity of structure, no seeds, no leafy stems, no vascular tissue, and by lack of chlorophyl and the consequent absolute *dependence* in the matter of food-supply. The conspicuous structures we have been studying are in reality the fructifications only of the several types. For Agarics, and such forms generally, the efficient, absorbing, or nutritive part lies unobserved, consists of myriads of hyphæ permeating in every direction the substratum, above which the fructification rises. By examining you may find some of these hyphæ in the locality whence your specimens come. If you have cultivated Agarics, ask the gardener what he means by "spawn."

LESSON LIV.

An Outline of the Vegetable Kingdom.

Materials required: Flowering plants in variety, Ferns, Mosses, Fungi; a vessel containing in water forms of fresh-water Algæ, Brook-silk, Ditch-moss, Water-net, any species that may be obtainable.[1]

I. THE ALGÆ: THE THALLOPHYTES.

These are not studied to advantage without the microscope and suitable equipment, but with our lenses we may nevertheless form some conception of their nature.

[1] Where marine Algæ are obtainable they may be used in this lesson instead of forms called for.

a. Observe the plants as they float in the water. Note their soft, flocculent structure; their bright color.

b. Float a little of the material out on pieces of stiff white paper, and examine with the Coddington. In the simpler forms the individual threads can be easily distinguished; in others, the filaments are seen to branch in various ways; but in all we are impressed with the extreme simplicity displayed in form and make-up. Under the microscope the filaments resolve themselves into rows of long, green cells. Mount in water, and examine with a low power.

c. Compare the structure of these plants with that of the Black Mould. Fruit aside, how do Algæ, as we see them, and Moulds agree? In what are they strikingly different? Remember that difference in color has respect to difference in *habit* — a difference which agreement of structure far outweighs.

The marine Algæ, as far as organization goes, differ from these simple fresh-water forms much as the larger Fungi differ from the Mould; it is chiefly a matter of form and size, not of structure.

d. We have before us, then, representatives of two great groups of plants, which, with much diversity in habit, color, and external particulars, agree substantially in their simplicity of structure. They have no real leaves or stems, no fibro-vascular tissues: they are simply masses of associated similar cells; and although presenting great variety in their methods of spore-production, these plants are yet all of them reproduced by simple spores. *Fungi* and *Algæ*, in the widest sense of

those terms, make up of the Vegetable Kingdom its first great sub-division, the:—

SUB-KINGDOM THALLOPHYTA.

II. The Bryophytes.

If, now, with these simple Thallophytes we compare Mosses and Liverworts, the advance in structure offered by the latter plants is very marked. Mosses are reproduced still by spores, it is true; but they never fail to show the sequence of phases which has been described, while leaf and stem attain in many of them perfect distinctness, and the stem in particular cases approaches the structure of the vascular stems of higher plants.

Spore-bearing plants which thus differentiate stem and leaf, and show an alternation of generations, make up the—

SUB-KINGDOM BRYOPHYTA.

III. Pteridophytes.

When, now, Ferns and their allies, the Scouring-rushes and Club-mosses, are compared with all the plants so far considered, their special characteristics come out prominently. In what particulars do Ferns agree with Liverworts and Mosses? Wherein lies the great structural difference? Notice that the particulars in which the Fern differs from the Bryophyte are those in which the Fern most resembles the flowering plants.

Accordingly, we say that all plants reproduced by spores, showing alternation of generations, and possess-

ing, furthermore, *fibro-vascular tissues*, go together to make the third great section of the Vegetable Kingdom, the —

SUB-KINGDOM PTERIDOPHYTA.

IV. SPERMAPHYTES OR PHANEROGAMS.

In comparison with all the plants in this lesson considered, the "flowering plants" seem distinct enough; these plants alone produce *seeds*. This distinction is really somewhat superficial,[1] but it is patent, and is associated with many characteristic structural details; as, for instance, in the matters of venation and vernation, the type of the fibro-vascular bundle, etc. But into the merits of the discussion we cannot now enter. We content ourselves with the statement that all seed-bearing plants unite to form the fourth and last grand division of the plant world, the —

SUB-KINGDOM SPERMAPHYTA.

V. Prepare an outline of the Vegetable Kingdom, writing in tabular form the names of the several principal sub-divisions, and placing opposite each the name of some familiar plant which may be regarded as an illustrative type.

[1] See Gœbel's "Outlines of Classification," pp. 209–309; and Vines's "Text-book of Botany," p. 431.

APPENDIX A.

Directions for Collecting and Preserving Materials.

INASMUCH as it is necessary to collect and prepare in advance a large part of the materials called for in these lessons, the following brief directions are presented, in the hope that they may be of assistance to the teacher.

The materials required may be grouped into four classes: —

I. Alcoholic materials.

II. Dry materials prepared without the application of pressure.

III. Herbarium specimens dried under pressure.

IV. Fresh materials.

The months during which the materials may be collected to the best advantage are in all cases indicated.

The lists hereinafter given will, of course, be enlarged upon by the live teacher.

I. ALCOHOLIC MATERIALS.

The materials which are to be preserved in alcohol should be collected, and, while fresh, dropped into 75 per cent alcohol.

All underground parts should be thoroughly washed in water, and all large specimens cut into pieces of suitable size for study, before being placed in alcohol.

The jars or bottles in which these specimens are preserved must be tightly corked when not in use in the class.

Alcoholic material will be found less brittle and easier to handle in the class if placed in water for an hour or more before being used.

In all cases where the pupil is to make a detailed study of any species or part a sufficient number of specimens should be collected to supply each member of the class with at least one.

These materials may be grouped as follows: —

a. Stems.

Pieces of Cornstalk and Pumpkin-vine, — July, August.
Twigs of Maple, any species, — May.
Stems of Poison-ivy, with roots, — All the year.

b. Rootstocks.

Solomon's-seal, *Polygonatum* — sp.
Trillium, any species.
Iris, any species.
May Apple, or Mandrake, *Podophyllum peltatum* L.
Bracken Fern, *Pteris aquilina* L.

These rootstocks may be collected from May until September.

c. Leaf-buds.

The unfolding leaf-buds of the following species should be collected in April and May: —

Apple or Crab, any species.
Common Violet, *Viola palmata*, var. *cucullata* Gray.
Currant, *Ribes rubrum* L.
Fern, any species.
Ground Ivy, *Nepeta glechoma* Benth.
Oak, any species.
Yellowdock, *Rumex*, any large species.

d. Flowers.

Flowers of Trillium if desired for very early study. These should be collected in April of the preceding year.

Double flowers of the Windflower, *Anemonella thalictroides* Spach; Strawberry; and any other species not ordinarily producing double flowers.

Flowers developing within or from other flowers, if obtainable. The Roses and Jessamine occasionally produce such flowers.

e. Fruits.

Blackberry, any species.
Gooseberry, any species.
Strawberry, any species.
Mulberry, any species.

The mature fruits should be collected in June and July.

Cherry, any cultivated species. Young specimens in which the stone is not yet formed, and specimens nearly mature, should be collected.

f. Liverworts.

Marchantia polymorpha L. Branches bearing fertile and sterile receptacles should be collected in May and June. The species occurs on damp, shaded banks, in greenhouses, etc.

Conocephalus conicus Dumort. Branches bearing the short, cone-shaped receptacles should be collected in October or November, and those with the fruiting receptacles on elongated pedicels in April or early May. Branches with sterile receptacles may be collected in May or early June. The species grows commonly on moist, shaded banks and bases of bluffs.

II. Dry Materials Prepared Without Pressure.

Dry all materials of this kind rapidly, to prevent

moulding, and store the more perishable kinds in boxes, to prevent breakage. Place moth-balls (naphthalin) with the specimens, to prevent attacks of insects.

The materials in this section may be grouped as follows: —

a. Stems.

Of these one specimen of each will answer for the entire class.

1. Specimens of the following stems need not exceed a foot in length.

Corn, stem.
Corn, the base of stalk, showing roots.
Grape, attached to its support by tendrils.
Virginia Creeper, attached to its support by disks.
Stems attacked by Dodder.
Morning-glory twining around a string or stick.
Elder, *Sambucus canadensis* L.

2. Longer specimens of the following are desirable:

Pumpkin-vine.
Strawberry runner.

All the preceding specimens may be collected during the summer.

3. Wood-sections of the following species are desirable: —

Box Elder.
Oak, any species.
Pine, any species.
Cherry, any species.
Locust, *Robinia pseudacacia* L.
Palm, any species, to be obtained by exchange or purchase.
All trees studied in the lessons as types of orders.

These may be collected at any season of the year, but preferably in the fall or winter, and should be prepared as follows: —

Collect stems not less than six inches in diameter, and, after seasoning, cut them into uniform pieces six or eight inches long, and then cut each piece longitudinally through the centre, being careful not to injure the bark. Plane or polish the cut ends and faces.

b. Fruits.

Collect the mature fruits of the species in the following list in sufficient quantity to supply each member of the class with at least one specimen of each kind. The fruits are here grouped according to the months during which they should be collected.

1. June or early July: —

Maple,	*Acer*, any species.
Marsh-marigold,	*Caltha palustris* L.
Pea,	any cultivated form.
Poppy,	any cultivated form.
Lilac,	any cultivated form.

2. September and early October: —

Burdock,	*Arctium lappa* L.
Butternut,	*Juglans cinerea* L.
Corn,	*Zea mays* L.
Goosefoot,	*Chenopodium album* L.
Jimson-weed,	*Datura*, either species.
Milkweed,	*Asclepias*, any species.
Tick-trefoil,	*Desmodium*, any species.
Sunflower,	cultivated or native forms.
Rose,	cultivated or native forms.
Balloon-vine,	*Cardiospermum haliacabum* L.
Thistle,	*Cnicus*, any species.
Spanish-needles,	*Bidens*, any species.
Hazel,	*Corylus*, either species.

Tobacco,	any cultivated form.
Pine,	*Pinus*, any species. (This may also be collected later in the year.)

3. All summer: —

Purslane,	*Portulaca oleracea* L.
Black mustard,	*Brassica nigra* Koch.
Shepherd's-purse,	*Capsella bursa-pastoris* Mœnch.

c. Seeds.

Seeds of the bean, pea, and catalpa should also be on hand. The last may be collected in September.

d. Mosses.

When it is desired to preserve specimens of mosses for study they may be dried in mass by exposure to the warm air of a room. When they are to be used they may be revived by being placed in a moist chamber under a bell-glass or other suitable dish or vessel, or simply by being watered and covered with a wet cloth.

Mosses in fruit may be collected in May and June, and also in September and October.

III. Herbarium Specimens Dried Under Pressure.

For preparing herbarium specimens, use *driers* made of ordinary carpet paper, cut into sheets twelve by eighteen inches. Any other soft, porous paper will answer.

Alternate one, two, or three driers with *folders*, folded sheets of printers' or other light paper (old newspapers will answer), in which the plants to be dried are placed.

Subject the whole to a pressure of fifty to one hundred pounds, which may be conveniently applied by placing on the package a board of the same size as

the driers, on which blocks of wood or stone, or other convenient weights, may be placed.

Replace the driers by other dry ones daily during the first four or five days, and after that for a week or two at longer intervals, until the specimens are thoroughly dried. After each change, spread the driers out to dry.

Examine the specimens at the first change of driers, and straighten out all folded parts, and thereafter simply shift the folders containing the specimens from one set of driers to another.

Two sets of herbarium specimens should be prepared, one containing the materials required for the preliminary or general lessons, the other a complete set of local plants, including cultivated ones, for comparison and reference in the subsequent lessons.

a. Materials for General Lessons.

Prepare the specimens to be used for this purpose by the above described method, and fasten them securely by narrow gummed strips to sheets of cardboard or other stiff paper, each sheet containing specimens illustrating the variation in one character; as, for example, one sheet of leaves illustrating different kinds of venation, another illustrating different kinds of forms, another showing margins, etc.

The specimens may then be marked either with the name of the species or by numbers referring to a list.

Prepare a full set of sheets of this kind for every two pupils in the class, as more than two cannot conveniently work with one sheet.

When not in use these sheets may be kept in boxes or packages, with a liberal supply of naphthalin.

These specimens may also be left unmounted, and kept in packets; but they are then more likely to be broken.

The materials in this section may be conveniently grouped as follows: —

1. *Stems or Branches with Leaves.*

These may be collected in May and June: —

Larch,	*Larix*, either species.
Gooseberry,	any species. Both branches with tufted leaves and those with spines should be collected.
Painted-cup,	*Castilleia coccinea* Spreng.
Barberry,	*Berberis vulgaris* L. Young branches.
Locust,	*Robinia pseudacacia* L. Young branches with spines.
Shepherd's-purse,	*Capsella bursa-pastoris* Mœnch. The whole plant.
Peppergrass,	*Lepidium virginicum* L. Entire young plants, before flowering.
Smilax,	*Myrsiphyllum* — sp. (These can be obtained at any time in any hot-house.)
Goose-grass,	*Galium*, any species.
Carpetweed,	*Mollugo verticillata* L.

2. *Leaves.*

Do not break off the petiole and stipules when these are present. Leaves may be collected from May to September.

Collect and prepare as many of the following forms as possible: —

Apple,	*Pyrus malus.*
Barberry,	*Berberis vulgaris* L.
Bellwort,	*Uvularia*, either species.
Blackberry,	*Rubus villosus* Ait.

Black Willow,	*Salix nigra* Marsh.
Burdock,	*Arctium lappa* L.
Calla,	*Richardia africana* Kunth.
Canna,	*Canna*, any species.
Cherry,	*Prunus cerasus* L.
Day Lily,	*Hemerocallis*, either species
Elm,	*Ulmus*, any species.
Flowering Fern,	*Osmunda claytoniana* L.
Golden Currant,	*Ribes aureum* Pursh.
Ground Ivy,	*Nepeta glechoma* Benth.
Hawthorn,	*Cratægus*, any species.
Hazel,	*Corylus americana* Walt.
Honey Locust,	*Gleditschia triacanthos* L.
Honeysuckle,	*Lonicera sempervirens* Ait., or *sullivantii* Gray.
Locust,	*Robinia pseudacacia* L.
Maple,	*Acer*, any species.
Morning-glory,	*Ipomœa purpurea* Lam.
Mullein,	*Verbascum thapsus* L.
Nasturtium,	*Tropœolum majus* L.
Pea,	any cultivated form.
Plantain,	*Plantago major* L.
Purslane,	*Portulaca oleracea* L.
Red Clover,	*Trifolium pratense* L
Red Currant,	*Ribes rubrum* L.
Rose,	any species.
Rue Anemone,	*Anemonella thalictroides* Spach.
Smartweed,	*Polygonum*, any species. Collect with stem.
Sunflower,	*Helianthus*, any species.
Sweet Clover,	*Melilotus alba* Lam.
Thistle,	*Cnicus*, any species.
Violet,	*Viola palmata*, var. *cucullata* Gray.
White Oak,	*Quercus alba* L.

3. *Flower Clusters.*

For practical purposes the fruit-clusters will answer quite as well.

Collect the specimens in the spring or early summer.

The following will be found useful: —

Blue Grass,	*Poa pratensis* L.
Carrot,	*Daucus carota* L.
Elder,	*Sambucus canadensis* L.
Grape,	*Vitis*, any species.
Larkspur,	*Delphinium*, any species.
Lily-of-the-valley,	*Convallaria majalis* L.
Mandrake,	*Podophyllum peltatum* L.
Phlox,	any species with flat-toped cluster.
Plantain,	*Plantago major* L.
Poplar,	*Populus*, any species.
Shepherd's-purse,	*Capsella bursa-pastoris* Mœnch. Young and old flower clusters.
Wheat,	*Triticum vulgare*.
White Ash,	*Fraxinus americana* L.
Wild Sarsaparilla,	*Aralia nudicaulis* L.

a. Materials for a Herbarium.

A herbarium of local plants should be prepared for use in every school. Press the specimens as heretofore, using now the entire plant, including root, where practicable.

When the roots are thick they should be trimmed down, and they should always be washed before being placed in press.

Of large specimens take branches with leaves and flowers, and, where practicable, fruits.

When the specimens are properly pressed they should be mounted on sheets of rather stiff white paper by strips of gummed paper.

For this purpose sheets measuring eleven by sixteen inches are convenient.

A label bearing the name, habitat, place, and date of collecting, should then be placed in the lower right-hand corner.

The species of one genus, or even order, may then be placed together into a sheet of manilla or other heavy paper, with the name of the genus or order written on the outside, or they may all be bound together in a portfolio.

When not in use, the specimens should be kept in a box or case with naphthalin.

A herbarium of this kind is valuable for reference, and comparison with unclassified material.

Pupils will find it an interesting task to prepare a herbarium for the school.

IV. Fresh Materials.

The various fresh materials required, such as twigs, leaves, flowers, fruits, roots, leaf-buds, etc., should be located and observed beforehand, so that they can be collected promptly when needed.

House-plants will be found very useful here.

This work may be largely subdivided among the pupils.

APPENDIX B.

For Lessons VII., IX., X., and XI., in which special materials are required, a few general directions may be helpful.

1. As to Seed-sowing.

Seeds of nearly all sorts germinate sufficiently well for our purpose in what is everywhere familiarly called a hot-bed, a simple box of moist sand or earth covered by glass. The soil should be kept moist, but not wet. By baking in the oven once or twice prior to use the soil is less liable to be affected with weeds. After planting the seeds of whatever varieties in marked rows, place the box in the light in some part of the schoolroom where it is not likely to be disturbed, and where the temperature is pretty constant. The whole matter may sometimes be safely intrusted to an intelligent janitor. It is, however, essential to let the pupils watch as much as possible all the stages of the cultivation.

Seeds should be sown in materials in different boxes; some in rich soil, some in clean sand as free from soil as possible, some in sawdust; this to illustrate the various modes of germination and the function performed by roots (Lesson X.). The supply in all cases should be sufficient to furnish a liberal amount of material for experiments illustrating the function of green foliage (Lesson XI.). Seeds should also be planted in different

positions, right side up, wrong side up, etc., to illustrate LESSON X.

For the study of Black Mould (LESSON LIV.) material may always be maintained by placing a little stable-manure (fresh) under a bell-jar on a plate containing the sufficient water to insure a moist atmosphere. Once mould fruits, cultures can be established on moist bread, boiled potatoes, or other convenient material.

The following common seeds germinated and appeared above ground in the time specified for each. The sowing was in common garden earth. The temperature varied from 70° Fahrenheit by day to 50° during the night, all the time under glass: —

	HOURS.		HOURS.
Beet	96	Squash	168
Cucumber	140	Sweet Corn	78
Field Corn	78	Sweet Pea	102
Lettuce	60	Tomato	120
Oats	78	Turnip	48
Onion	144	Watermelon	124

The time will vary somewhat with circumstances of temperature, depth of planting, etc. From four to ten days may be counted upon as necessary in all cases.

2. BUDDING BRANCHES.

After midwinter, branches of various trees will bud in the schoolroom at its ordinary temperature (unless too low at night, of course) if the branches be smoothly cut off, and the cut ends be immersed in clean water. It is better, also, to occasionally change the water. Lilac, Cherry, and Maple do well to start with. These three will come out in full bloom in January. All do better if the air about them be not too dry.

APPENDIX C.

BOOKS OF REFERENCE.

1. For Classification and Description.

GRAY'S *Manual.* Sixth Edition.
GRAY'S *School and Field Book.* Latest Edition.
WOOD'S *Botanist and Florist.*
APGAR'S *Trees of North America.*
Forest Trees of North America. Report of the Tenth Census of the U. S., vol. ix.
UNDERWOOD, *Our Native Ferns and Their Allies,*
EATON'S *Ferns of North America.*
GOEBEL, *Outlines of Classification.*
VINES, *The Student's Textbook of Botany.* 2 vols.
LESQUEREUX AND JAMES, *Mosses of North America.*
BARNES, *Keys to Genera and Species of Mosses.* (Chas. R. Barnes, Madison, Wis.)

2. For Structure and Function.

BESSEY'S *Botany.*
ARTHUR BARNES AND COULTER, *Plant Dissection.*
GRAY'S *Structural Botany.*
GOODALE'S *Physiological Botany.*
LUBBOCK'S *Flowers, Fruits, and Leaves.*
MÜLLER'S *Fertilization of Flowers.*
DARWIN, *Cross and Self-Fertilization of Plants.*
DARWIN, *Movements and Habits of Climbing Plants.*
DARWIN, *Insectivorous Plants.*
KERNER, *Flowers and Their Unbidden Guests,*

3. General Botany.

GEDDES, *Chapters in Modern Botany.*
MARSHAL WARD, *The Oak.*
MARSHAL WARD, *Timber, and Some of Its Diseases.*
KERNER'S *Plant Life.* 2 vols.

4. Journals.

Botanical Gazette, Madison, Wis.
Bulletin Torrey Botanical Club, Columbia College, New York.
Garden and Forest, New York.
Science, New York.

APPENDIX D.

GLOSSARY AND INDEX.

[The numbers refer to the pages, except where otherwise stated.]

Acaulescent, 132.
Accessory buds, 4.
Achenium, 80.
Acrogens, 184.
Actinomorphic, 75, 148.
Acuminate. Tapering into a long point; 49.
Acute. Forming or ending in an acute angle; 49.
Adnate. A term applicable to an anther when attached along its whole length to the filament; 73. To the lamellæ of an Agaric when grown fast to the stipe; 201.
Adventitious buds, 28, 35.
Aerial roots, 35.
Æstivation, 72.
Agaricine. Like a toadstool or mushroom; 203.
Aggregated fruits, 81.
Akene, see *achenium*.
Albumen, 84, 164, 173.
Albuminous seeds, 84.
Alburnum, 161.
Alcoholic materials, 209.
Alternation of generations, 185.
Ament. A catkin; 117.
Androecium, 65, 73.
Angiosperms, 156.
Annulus, 186, 187, 201.
Anther, 65, 73.
Antheridial branch, 196.
Anthesis, 135.
Anthotaxy, 59.
Apetalous. Without petals.
Areolation, 194.
Areole, 194.
Ascending axis. The stem; 33.
Assimilation, 41.
Auriculate. With ear-shaped appendages at base; 49.
Axile placenta, 74.

Bark, 10, 12, 20; inner bark, 11; middle bark, 11; outer bark, 11.
Bast, 11.
Bifid. Cleft into two parts; 107.
Blade of leaf, 38.
Blight. Mildew; a term applied to several forms of Fungi parasitic on the growing parts of flowering plants; 203.

Books of reference, 222, 223.
Bracts, 58, 60.
Buds, arrangement of, 2, *et seq.;* axillary, 3; development of, 29, *et seq.;* lateral, same as axillary, 30, 31; on roots, 33, 34; structure, 29, *et seq.;* terminal, 3, 30, 31.
Bud-scales, 57.
Bulb, 28.
Bulb-scales, 28, 57.

Caducous. Falling off very early; 162.
Calyptra, 192.
Calyx, 64, 71.
Cambium, 16, 17, 21.
Capsule, of flowering-plants, 82, 83; of liverwort, 195; of moss, 191, 192.
Carpel, 74, 78.
Carpellary. Pertaining to a carpel.
Caryopsis, see *grain.*
Catkin, 61.
Caulicle, 174.
Cells, 11, 20; of anther, 65; of ovary, 66, 74.
Cespitose. In tufts.
Chaff, 138.
Chlorophyl-grains, 39.
Cilia. Delicate, hair-like structures; marginal hairs; 107.
Circinate. Spirally coiled; 55,184.
Circumcissile. Breaking by a transverse suture; 82.
Cirrhose, or **cirrhous.** Ending in a tendril; 53.
Cladophyllum, 39.
Cleft. Sharply cut about halfway, with acute sinuses; 51. Pinnately cleft, 52; palmately cleft, 52.
Cleistogamous flowers, 147, 148.
Compressed. Flattened laterally; 56.
Conduplicate. Folded lengthwise along the midrib; 55.
Cone, 83, 154, 155, 158, 159.
Connate-perfoliate. Having the bases of opposite leaves grown together around the stem; 49.
Connective, 65.
Convolute. Rolled up from one edge; 55.
Cordate. Heart-shaped; 47, 49.
Coriaceous. Leathery; 55.
Cork, 11.
Corolla, 64, 71.
Cortex, 10, 17, Fig. 6; 18, Fig. 7; 20, Fig. 8; 189.
Cortical. Pertaining to the cortex; 17, 18, 20.
Corymb, 61.
Corymbose. Corymb-like, or a corymb; 123.
Cotyledons, 22, 84.
Crenate. With rounded teeth which are directed toward the tip; 50.
Crenate-dentate. With rounded teeth which are directed outwardly; 104.
Crenulate. Finely crenate; 51, 196.
Crescentiform. Shaped like a crescent; 195.
Cryptogams. Plants which do not produce flowers with stamens and pistils.
Culm, 169.

Cuneate. Wedge-shaped; 47, 49.

Cuspidate. With a short, abrupt tooth at the apex; 49.

Deciduous, leaves, 37; bud-scales, 31.

Decompound. Said of leaves when irregularly several times compound; 53.

Decurrent. Said of the blade of a leaf when it extends down on the stem, forming wings; 49.

Decussate, 2.

Dehisce. To break open along definite lines; 65, 79.

Dehiscence, in fruits, 82; in stamens, 73.

Deliquescent, 151.

Dentate. With sharp teeth whose points are directed outward; 51.

Denticulate. Finely dentate; 51, 191.

Descending axis. The root; 33.

Determinate inflorescence, 62.

Diadelphous, 73, 163.

Diandrous. With two stamens; 178.

Dichotomous veining, 188.

Diclinous, 117.

Dicotyledonous, 22.

Didynamous. The stamens in two pairs, one pair longer; 178.

Digitately-veined, 45.

Dicœcious. With staminate and pistillate flowers on different plants; 131.

Discoid. Disk-like; 196.

Disk, 75, 114; in composite flowers, 134.

Disk-flower, 137.

Dispersion, of fruits and seeds, 84

Distinct. Applied to stamens and other floral organs, when the parts of the set under consideration are not united with each other; 73.

Divided. Said of leaves, etc., when cut almost to the midrib or base, 51; palmately divided, 52; pinnately divided, 52.

Dorsal. Pertaining to the back; in the leaf, the lower surface.

Doubly crenate. Coarsely crenate, and the large crenations again crenate; 51.

Doubly dentate. Coarsely dentate, and the large teeth again dentate; 51.

Doubly serrate. Coarsely serrate, and the large teeth again serrate; 51.

Drupe. A stone-fruit; 81; see also fruit of cherry, 141.

Dry materials, lists, 211, 214.

Duramen, 161.

Elaters, 196.

Elliptical. Shaped like an ellipse; much longer than wide and with rounded ends, 48.

Emarginate. Indented by a shallow, rounded sinus; 49.

Embryo, 84.

Embryo-sac, 67.

Endogens, 22.

Entire. Without indentation or division; the margin even, whole; 51.
Epidermis, 14, 27, 39, 80.
Epigynous. Placed upon the pistil; 73.
Epipetalous. Placed upon or adnate to the corolla; 73.
Essential organs, 67.
Etærio, 81.
Even-pinnate. Ending in two leaflets; 53.
Ex-albuminous, 84, 164.
Excurrent, 151.
Exogenous stem, 20, Fig. 8; 23.
Exogens, 22, 23.
Ex-stipulate. Without stipules.
Extrorse. Turned outward, as an anther whose dehiscing side faces outward.

Family, 90.
Fascicle, 63.
Fascicled, 38.
Feather-veined, 45.
Fertile. Bearing fruit; 196.
Fertilization, process of, 67.
Fibrillose. Covered with delicate fibrils; 202.
Fibro-vascular bundles, in leaves, 40; in stems, 14.
Fibro-vascular tissues, 14, 207.
Filament, 65, 73.
Fleshy fruits, 81.
Floccose. In fleecy tufts, cottony; 54, 202.
Floral organs, 58.
Floret, 134.
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Follicle, 82.
Free-central placenta, 74.
Frond. The leaf of a fern; 183, 184.
Fructification. Fruit.
Fruit, 67, 78, 79; aggregated, 81; dehiscent, 79, 81; dry, 80; fleshy, 81; indehiscent, 79; multiple, 83; simple, 80; stone, 80.
Funiculus, 66.
Furcate. Dichotomously forking; 44.

Gamopetalous, 72.
Gamosepalous, 71.
Genus (pl. genera), 90, 96, 130.
Gemmæ, 195.
Gills (lamellæ), 201.
Glabrous. Smooth, without hairs or scales; 54.
Glandular. Covered with glands, or gland-like; 54.
Glaucous. Covered with a white bloom; 54.
Glomerule, 63.
Glumes, 171.
Grain. A dry, one-seeded fruit, packed with "albumen" in which the seed is imbedded; caryopsis, 80.
Gymnosperms, 156.
Gynœcium, 65, 74.

Habitat, 88.
Hairy. Covered with rather coarse, rigid hairs; 84.
Half-inferior, 74.
Half-superior, 74.
Head, 62; in composite flowers, 134.
Herbaceous, 23, 55.

Hesperidium, 81.
Hip. The aggregated fruit of the Rose, formed by the receptacle and calyx closing over the numerous akenes.
Honey-gland, or nectar-gland, 100, 127.
Host-plant, 35.
Hygroscopic. Possessing the property of hygroscopism; 186.
Hygroscopism, 85.
Hymenium, 201.
Hypha (pl. **hyphæ**), 197, 198.
Hypogynous. Placed on the receptacle; 72, 73.

Imbricated. Said of sepals, and also petals, when so placed in the bud that they overlap, some being wholly outside, others wholly inside, and still others partly in- and partly outside; 72.
Imperfect flowers. Such as lack either stamens or pistils, or both; 76.
Incised. Irregular, and sharply cut, less than half way to mid-rib or base; 51.
Indehiscent fruits, 79.
Indusium (pl. **indusia**), 187.
Inferior ovary, 74.
Inflexed. Bent inward, as leaves transversely folded so that the apex lies near the base; 55.
Inflorescence, 5; centrifugal, 62; centripetal, 60; determinate, 62; indeterminate, 60; mixed, 64; solitary, 63.
Innate. Borne upon. Said of the anther when attached by one end to the end of the filament; 73.
Internode, 2.
Introrse. Turned inward, as when an adnate anther faces inward; 13.
Involucre, 60, 130, 134; in ferns, 188.
Involute. Rolled inward; applied to both æstivation and vernation when the parts are longitudinally rolled inward from both edges in the bud; 55, 72.
Irregular flowers, 76.

Keel, 163.

Labiate. Two-lipped; 72.
Laciniate. Cut into a fringe; 104.
Lamellæ, 191, 201.
Lanceolate, or **lance-shaped.** A term applied to leaves, etc., in which the length is much greater than the width, the widest part being near the base; 47.
Lateral buds, or **axillary buds**, 30, 37.
Latex, 133.
Leaf, 37, *et seq.*; **apex**, 49; **arrangement**, 38; **base**, 48; **color**, 53; **compound**, 52; **division of blade**, 51; **duration**, 37; **form**, or **general outline**, 47; **functions**, 41; **margin**, 50; **parts**, 38; **simple**, 52; **special forms**, 56; **structure**,

39; surface, 54; texture, 55; venation, 44; vernation, 55.
Leaflets, 52.
Leaf-parenchyma, 39.
Legume, 82, 164.
Liber, 11.
Ligulate. Strap-shaped, like the rays of a sunflower; 72.
Ligule, 169.
Limb. Border; the spreading portion of salver-shaped, or funnel-formed calyx or corolla; 72.
Linear. Narrow; applied to leaves, etc., which are very narrow, and of nearly uniform width throughout; 48.
Linear-lanceolate. Narrowly lanceolate; 48.
Lobed. Divided into lobes; applied to a leaf, etc., which is cut about half-way, the sinus being obtuse; 51. Palmately lobed, 52; pinnately lobed, 52.
Loculicidal, 82.
Loculus (pl. **loculi**), 66, 74.
Lodicules, 172.
Loment. A legume which is notched so that it readily breaks into one-seeded segments; 82.

Medulla, 10.
Medullary rays, 15, 19.
Mesophyl. The pulpy middle part of the blade of a leaf; 170.
Micropyle, 67; 68, Fig. 9; 156.
Mid-rib, 44, 191, 195.
Monadelphous, 73, 163.
Monocotyledonous, 22.
Monœcious, 117.
Monopetalous, 72.
Monosepalous, 71.
Morphology of the flower, 71; of the root, 34.
Mucronate. Tipped with a projection of the mid-rib; 49.
Multiple fruits, 83.

Nectar-gland, or **honey-gland**, 100, 127.
Needle-shaped. Slender and rigid, as the leaves of the Pine; 48.
Nerves, on calyx, 175; in leaves, 46.
Node, 2.
Nodulose, 102.
Non-essential organs, 67, 70.
Nucleus, 68, Fig. 9.
Nut. A one-celled, one-seeded fruit with a hardened pericarp, and a cup-like involucre; 80.

Obcordate. Inversely heart-shaped; 48. Applied also to the apex when shaped like the base of a cordate leaf; 49.
Oblanceolate. Inversely lanceolate; 47.
Oblong. Longer than broad; applied to leaves, etc., which are widest at the middle, have rounded ends, and are more than twice as long as their greatest width; 48.
Oblong-ovate. Like the ovate form, but widest at the middle; 48.

Obovate. Inversely ovate; 47.
Odd-pinnate. Applied to pinnately compound leaves which end with one leaflet; 53.
Oöphytic, 186, 193.
Oösphere, 67; 68, Fig. 9; 185, 193, 197.
Oöspore, 69.
Opposite, buds, 5; leaves, 38. Applied also to the parts of the flower when those of one set are in the same radial line with those of the adjacent sets; 73.
Operculum, 192.
Order, 90.
Oval. Broadly elliptical, the length less than twice the greatest width; 48.
Ovate. Nearly the same as oval; applied to leaves, etc., which have the length not more than two-and-one-half times the greatest width, and which are widest near the base; 47.
Ovate-lanceolate. A term descriptive of forms intermediate between ovate and lanceolate; 48.
Ovary, 66; 68, Fig. 9; 74.
Ovules, 66; 68, Fig. 9.

Palets, 171.
Panicle, 62.
Panicled. Arranged in a panicle.
Papilionaceous, 72, 163.
Pappus, 135.
Parasites, 35, 203.
Parenchyma, 13, 40.
Parted. As applied to leaves, etc., cut more than half-way to the base or mid-rib, but not so deeply as to be divided; 51. Palmately, 52; pinnately, 52.
Pedicel, 60, 196.
Pedicellate. Having a pedicel; 61, 63.
Peduncle, 63.
Peltate. Shield-shaped; applied to a leaf which has the petiole attached near the centre of the blade, or at least above the basal margin; 49.
Pepo. A fleshy fruit with a hard rind; 81.
Perennial. Enduring; lasting year after year; 26.
Perfect flowers, 75.
Perfoliate. Passing through the leaf; a term applied to a leaf when its base is united around the stem, the latter appearing to pass through the leaf; 49.
Perianth, 64.
Pericarp, 80, 81.
Perigynous, 72, 73.
Peristome, 192.
Petaloid. In color and appearance like a petal.
Petals, 64, 72.
Petiole, 38, 56.
Petiolules, 52.
Pileus, 200.
Pinna (pl. **pinnæ**). One of the first, or main, divisions of a frond; 184.
Pinnatifid. Deeply and irregularly pinnately cleft; 52.

Pinnule. One of the divisions of a pinna; 185.
Pistil, 65, 74; compound, 75; simple, 74.
Pistillate flower. One having pistils, but no stamens; 154.
Pitted. Covered with minute depressions; 84.
Placenta (pl. **placentæ**), 66, 74.
Placentation, 66.
Plan of flower, 76, Fig. 10.
Plant-hairs, 122.
Plicate. Plaited like a fan; æstivation, 72; vernation, 55.
Plumule, 22, 84, 173.
Pollen, 65, 73.
Pollination, 70.
Polypetalous, 72.
Polysepalous, 71.
Pome, 81; see fruit of apple, 141.
Prothallus, 185.
Puberulent. Covered with minute down; 54.
Pubescent. Downy with soft hairs; 54.
Pulvinus, 161.
Pyxis. A capsule opening by a lid; 83.

Raceme, 61.
Racemose. Arranged in a raceme; 123.
Radicle, 22, 69, 84, 173.
Ray-flower, 137.
Receptacle, 66, 196.
Reduplicate. Turned backward, as when the edges of the leaves are turned outward in the bud; 72.
Regular flower, 75.
Reniform. Kidney-shaped; 47, 49.
Repand. Wavy, like the margin of an open umbrella; 49.
Resin-ducts, 11.
Resupinate, 147.
Revolute. Having the margins rolled backward; 55.
Rhachis, 59, 170.
Rhizoids. Root-hairs; 190, 194.
Rhizoma, or **rhizome,** 26.
Root-cap, 173.
Root-hairs, 121, 168, 190, 194.
Roots, 32; compared with stems, 32; functions, 35, 36; morphology, 34; primary, 33; secondary, 33.
Rosaceous. Arranged like the petals of a normal Rose, like the flowers of the Cherry, etc.; 72.
Rostrum, 192.
Rotate. Wheel-shaped; the border, as of a corolla, spreading abruptly, and the tube short or wanting; 72.
Runcinate. Lobed or cleft, with the points of the divisions directed backward; 52.
Runners, 147.
Rust. The common name of certain Fungi parasitic on the leaves of Grasses, etc.; 203.

Sagittate. Arrow-shaped; 47, 49.
Salver-shaped. In the form of a salver; a term applied to corollas, etc., with narrow tube and abruptly spreading, flat limb; 72.
Samara, 80, 95.
Saprophytic, 203.
Scabrous. Rough; 54.

Scales, bud, 29; bulb, 28; in composite flowers, 134.
Scape, 60.
Scurfy. Covered with epidermal scales; 202.
Scutellum, 173.
Seed, 67, 79, 83.
Seed-sowing, 220.
Sepals, 64, 71.
Septa, 74.
Septate. With partitions or septa; 198.
Serrate. With sharp teeth directed toward the apex; 51.
Serrulate. Finely serrate; 51.
Sessile, flowers, 61, 63; leaves, 60.
Seta, 191.
Silicle. A short silique; 83.
Silique. An elongated pod, with two valves which at maturity break away from a middle false partition, as in Black Mustard; 83.
Sinuate. Wavy; 51.
Sinus, 48, 50.
Sorosis. A fleshy multiple fruit, as the Mulberry, Osage-orange, etc.; 83.
Sorus (pl. **sori**), 187.
Spadix, 61.
Spathe, 61.
Spatulate. Shaped like a spatula; with a broad, rounded tip tapering to the base; 47.
Species, 95, 96.
Spicate. Arranged in spikes; 170.
Spike, 61.
Spikelet, 170.
Sporangia, 186, 198.
Spores, 185, 192, 193, 197, 198.
Sporophytic, 186, 193.
Stamens, 65, 73; insertion, 73; union, 73.
Staminate flower. One having stamens but no pistil.
Standard, 163.
Starch, 27.
Stellate. Radiating, star-shaped.
Stems, 10, *et seq.*; compared with roots, 32; cross-section, 20; habit, 25; kinds, 21, 24; structure, 12, *et seq.*
Sterile. Not bearing fruit.
Stigma, 66; 68, Fig. 9; 74.
Stigmatic surface, 66; 68, Fig. 9.
Stipe, 184, 200.
Stipules, 38, 56.
Stoma (pl. **stomata**), 39, 43, 151, 194.
Strap-shaped, see *ligulate*, 139.
Strobile, see *cone*, 83.
Style, 66; 68, Fig. 9; 74.
Style-arm. One of the stigmatic branches in composite flowers; 135.
Succulent. Fleshy, juicy; 54.
Superior ovary, 74.
Supervolute. Descriptive of a corolla that is plaited, and then convolute in the bud; 72.
Suture, 82.
Symmetrical flower, 76.
Syngynesious, 73, 135.

Tendrils, 56, 57.
Terete. Cylindrical, or nearly so; 56.

Testa, 83.
Thalloid. Thallus-like, not showing a distinct differentiation into stem and leaves; 194.
Thyrsus, 62.
Tomentose. Woolly; 54.
Tomentum. Wool; 133, 184.
Torus, 66, 75.
Transpiration, 43.
Triadelphous. United into three sets by the filaments; 73.
Tribes, 130, 142.
Trichomes, 122.
Truncate. Blunt; as if cut off abruptly; 49.
Tryma, 81.
Tuber, 26.
Typical flower, 76.

Umbel, 61.
Undulate. Wavy; 51.
Unsymmetrical flower, 76.
Utricle. A one-seeded dry fruit, much like the grain, but enclosed in a membranous sac or covering; 80.

Valvate. A term descriptive of a form of æstivation when the sepals or petals in bud come together only at their edges, and do not overlap; 72.
Valves, 82.
Veil. A film or covering which in many Agarics at first unites the edge of the pileus with the stipe; 202.
Venation, 39; kinds, 44.
Vernation, 55, 184.
Versatile. Free to turn; a term applied to the anther when attached at its middle to the end of the filament; 73.
Verticillaster, 63.
Verticillate. Whorled.
Vexillum, 163.
Villose. Covered with long, weak hairs; 54.
Viscid. Sticky; 104.

Whorled, 38.

Zygomorphic. Irregular; 76, 148.